Universidad de Oviedo

Creatividad y Funciones Ejecutivas: evaluación, desarrollo y perspectivas inclusivas en contextos de realidad virtual

Creativity and Executive Functions: assessment, development and inclusive perspectives in virtual reality contexts.

Tesis Doctoral

Programa de Doctorado en Educación y Psicología

Autora: Tania Pasarín Lavín

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RESUMEN DEL CONTENIDO DE TESIS DOCTORAL

1.- Título de la Tesis	
Español/Otro Idioma: Creatividad y Funciones Ejecutivas: evaluación, desarrollo y perspectivas inclusivas en contextos de realidad virtual	Inglés: Creativity and Executive Functions: assessment, development and inclusive perspectives in virtual reality contexts

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RESUMEN (en español)

La creatividad, entendida como la capacidad de generar ideas originales y útiles, y las funciones ejecutivas (FE), que incluyen habilidades cognitivas como la memoria de trabajo y la flexibilidad cognitiva, son competencias esenciales para el desarrollo académico y social. La creatividad permite la resolución de problemas de manera innovadora, mientras que las FE son clave para la autorregulación, la planificación y la adaptación a entornos cambiantes. Por ello, esta Tesis Doctoral, que se presenta como compendio de publicaciones, con tres trabajos publicados en revistas de impacto y uno complementario enviado para revisión, explora la interrelación entre la creatividad y las funciones ejecutivas en adolescentes, con un enfoque particular en poblaciones neurotípicas y neurodivergentes.

Para ello, la investigación se estructura en tres fases metodológicas:

En la primera fase, se realiza una revisión sistemática de la literatura para identificar las principales lagunas existentes en la investigación sobre la relación entre la creatividad y las FE en adolescentes. Los resultados, en este sentido, mostraron que la flexibilidad cognitiva tiene una relación positiva con la creatividad, mientras que el control inhibitorio se relaciona inversamente con la producción de ideas originales. Asimismo, la memoria de trabajo no presentó una relación directa con la creatividad, lo que sugiere que el pensamiento divergente no depende necesariamente de esta capacidad.

En la segunda fase, a través de dos estudios empíricos, se examinó cómo evolucionan estas habilidades a lo largo de la adolescencia, y cómo varían en función del perfil neurocognitivo, comparando entre estudiantes neurotípicos y neurodivergentes. Los hallazgos indicaron que, mientras las FE, como la planificación y la memoria de trabajo, tienden a mejorar con la edad, la creatividad figurativa parece disminuir a medida que los adolescentes avanzan en su educación. Sin embargo, la creatividad verbal se mantuvo estable durante el desarrollo adolescente. Además, se encontró que los adolescentes con TDAH destacaban en creatividad verbal, mientras que aquellos con dislexia mostraron mayor originalidad en creatividad figurativa y los estudiantes con discapacidad intelectual obtuvieron las puntuaciones más bajas en creatividad verbal.

Finalmente, en la tercera fase se realiza un análisis más avanzado mediante análisis de perfiles latentes para identificar diferentes perfiles creativos en adolescentes. Este enfoque permitió la identificación de tres perfiles creativos distintos. En este contexto, los resultados indicaron que los perfiles con alta creatividad verbal incluyeron estudiantes con necesidades educativas específicas, mientras que no se observaron diferencias significativas en creatividad figurativa.

En conjunto, los resultados de esta Tesis Doctoral evidencian la relación entre la creatividad y las FE en adolescentes, revelando que la flexibilidad cognitiva es clave para la creatividad, ya que facilita la generación de respuestas originales. Asimismo, un menor control inhibitorio

también se asocia con más creatividad, al permitir ideas menos convencionales. Sin embargo, la memoria de trabajo no mostró una relación clara.

Por otro lado, en cuanto al desarrollo evolutivo, FE como la planificación y la memoria de trabajo mejoran con la edad. Sin embargo, mientras que la creatividad verbal se mantiene estable, la creatividad figurativa tiende a disminuir. Además, se observaron diferencias significativas en creatividad y FE entre perfiles neurocognitivos. Por ejemplo, los adolescentes con TDAH destacan en creatividad verbal, mientras que los estudiantes con dislexia sobresalen en creatividad figurativa.

En resumen, esta Tesis Doctoral resalta la necesidad de enfoques educativos personalizados que promuevan tanto la creatividad como las FE, considerando la diversidad de perfiles cognitivos y creativos, ya que podría ser útil para potenciar al máximo el talento.

RESUMEN (en Inglés)

Creativity, understood as the ability to generate original and useful ideas, and executive functions (EF), which include cognitive skills such as working memory and cognitive flexibility, are essential competencies for academic and social development. Creativity enables innovative problem solving, while EFs are key to self-regulation, planning and adaptation to changing environments. Therefore, this Doctoral Thesis, which is presented by compendium of publications, with three papers published in impact journals and a complementary one submitted for review, explores the interrelationship between creativity and executive functions in adolescents, with a particular focus on neurotypical and neurodivergent populations.

For this purpose, the research is structured in three methodological phases:

In the first phase, a systematic literature review is conducted to identify the main existing gaps in the research on the relationship between creativity and EF in adolescents. The results showed that cognitive flexibility is positively related to creativity, while inhibitory control is inversely related to the production of original ideas. Likewise, working memory did not show a direct relationship with creativity, suggesting that divergent thinking is not necessarily dependent on this ability.

In a second phase, through two empirical studies, we examined how these skills develop during adolescence, and how they vary as a function of neurocognitive profile, comparing neurotypical and neurodivergent students. The findings indicated that while EF such as planning and working memory improved with age, figurative creativity tended to decline as adolescents progressed in their education. However, verbal creativity remained stable throughout adolescent development. In addition, it was found that adolescents with ADHD excelled in verbal creativity, while those with dyslexia showed greater originality in figurative creativity and students with intellectual disabilities scored lowest in verbal creativity.

Finally, in the third phase, a more advanced analysis was performed using latent profile analysis to identify different creative profiles in adolescents. This approach allowed the identification of three distinct creative profiles. In this context, the results indicated that profiles with high verbal creativity included students with special educational needs, while no significant differences were observed in figurative creativity.

Overall, the results of this Doctoral Thesis show the relationship between creativity and EF in adolescents, revealing that cognitive flexibility is key to creativity, as it facilitates the generation of original responses. Likewise, less inhibitory control is also associated with more creativity, as it allows for less conventional ideas. However, working memory did not show a clear relationship.

On the other hand, in terms of evolutionary development, EF such as planning and working

memory improve with age. However, while verbal creativity remains stable, figurative creativity tends to decrease. In addition, significant differences in creativity and EF were observed between neurocognitive profiles. For example, adolescents with ADHD excel in verbal creativity, while students with dyslexia excel in figurative creativity.

In summary, this Doctoral Thesis highlights the need for personalized educational approaches that promote both creativity and EF, considering the diversity of cognitive and creative profiles, as it could be useful to maximize talent.

SR. PRESIDENTE DE LA COMISIÓN ACADÉMICA DEL PROGRAMA DE DOCTORADO EN EDUCACIÓN Y PSICOLOGÍA

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Listado de trabajos

Publicaciones:

Pasarín-Lavín, T., Abín, A., García, T. & Rodríguez, C. (2023). Relationship between Executive Functions and Creativity in Children and Adolescents: A Systematic Review. *Children*, *10*, 1002. https://doi.org/10.3390/children10061002

Pasarín-Lavín, T., García, T., Rodríguez, C., Núñez, J.C., y Areces, D. (2024). Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity. *Thinking Skills and Creativity*, *51*, 101466. https://doi.org/10.1016/j.tsc.2024.101466

Pasarín-Lavín, T., García, T., Abín, A., & Rodríguez, C. (2024). Neurodivergent students. A continuum of skills with an emphasis on creativity and executive functions. *Applied Neuropsychology: Child*, 1–13. https://doi.org/10.1080/21622965.2024.2406914

Estudio Complementario:

Pasarín-Lavín, T., García, T., Rodríguez, C., & Núñez, J.C. (under review). Latent Profile Analysis of Creativity: Relations with Intelligence and Executive Functions. *Developmental Neuropsychology.*

Índice

RESUMEN

La investigación de la relación entre la creatividad y las funciones ejecutivas (FE) en adolescentes es de gran relevancia para comprender cómo estas capacidades cognitivas interactúan durante una etapa clave del desarrollo. La adolescencia es un periodo en el que el cerebro experimenta cambios significativos que influyen en la forma en que los jóvenes procesan información, resuelven problemas y expresan su creatividad. Además, las FE, que incluyen habilidades como la planificación, la memoria de trabajo, la flexibilidad cognitiva y el control inhibitorio, son fundamentales para el rendimiento académico y la adaptación a las demandas de la vida diaria. Dado que la creatividad se considera una habilidad crucial para el éxito en el mundo actual, entender cómo estas dos áreas se relacionan puede ofrecer valiosas perspectivas sobre el diseño de intervenciones educativas y programas de desarrollo personal.

El objetivo principal de esta Tesis Doctoral ha sido investigar cómo las FE y la creatividad se relacionan en adolescentes, abordando este tema desde diferentes ángulos que permiten no solo comprender esta relación, sino también observar su evolución, variabilidad según el perfil neurocognitivo, y la identificación de perfiles creativos. Para abordar este objetivo se sigue un enfoque metodológico dividido en tres fases alineadas con los siguientes objetivos específicos:

1. Analizar la relación entre las FE y la creatividad en niños y adolescentes. A partir de esta revisión inicial, se busca mapear las principales lagunas en la literatura y fundamentar los siguientes estudios. Estudio Publicado 1: *"Relationship between Executive Functions and Creativity in Children and Adolescents: A Systematic Review".*

2. Examinar el desarrollo evolutivo de la creatividad y las FE a lo largo de la adolescencia, analizando cambios y relaciones a lo largo de esta etapa de transición. Este estudio explora cómo las FE y la creatividad se modifican con el tiempo en función de la edad y otros factores contextuales. Estudio Publicado 2: *"Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity".*

3. Comparar la creatividad y las FE en diferentes perfiles neurocognitivos: adolescentes neurotípicos y neurodivergentes. El análisis de las diferencias entre estos grupos permitirá identificar cómo varían las trayectorias de desarrollo

cognitivo y creativo, y aportará información valiosa para el diseño de intervenciones inclusivas. Estudio publicado 3: *"Neurodivergent Students. A Continuum of Skills with an Emphasis on Creativity and Executive Functions"***.**

4. Identificar la existencia de perfiles creativos en adolescentes a través de un análisis de perfiles latentes, analizando factores como la neurodiversidad, el género, la inteligencia y la edad y explorando las implicaciones de estos perfiles en su desarrollo cognitivo. Este objetivo permitirá identificar grupos específicos que puedan beneficiarse de intervenciones educativas personalizadas. Estudio Complementario 1: *"Latent Profile Analysis of Creativity: Relations with Intelligence and Executive Functions"*

La **primera fase** consiste en una revisión sistemática de la literatura con el objetivo de analizar la relación entre las FE y la creatividad en niños y adolescentes, evaluando cómo estas capacidades cognitivas interactúan y se influyen mutuamente. Esta fase se desarrolló a través de una revisión sistemática de la literatura científica existente, plasmada en el Estudio Publicado 1. Esta revisión sistemática reveló una relación significativa entre ciertas FE, en particular la flexibilidad cognitiva, y la creatividad. La capacidad para alternar entre diferentes tareas o enfoques mentales resultó ser un predictor clave en la generación de respuestas creativas, especialmente en el contexto adolescente. Además, se observó que el control inhibitorio tiene una relación inversa con la creatividad; un menor control inhibitorio puede facilitar respuestas menos convencionales, aumentando la originalidad en las ideas generadas.

Por otro lado, la investigación mostró que la memoria de trabajo no estaba directamente relacionada con la creatividad en esta muestra de adolescentes. Este resultado se explica en parte por las pruebas estándar de creatividad utilizadas, como el Test de Pensamiento Creativo de Torrance (TTCT), que no requieren una alta carga de memoria de trabajo. De manera similar, se descubrió que los adolescentes con niveles más bajos de atención tendían a producir respuestas más originales, lo que sugiere que una menor focalización puede facilitar el pensamiento divergente, una clave para la creatividad.

Esta primera fase concluyó que las FE, particularmente la flexibilidad y el control inhibitorio, desempeñan un papel crucial en la creatividad adolescente. A pesar de la variabilidad en las herramientas de evaluación tanto para las FE como para la creatividad, estos resultados proporcionan una base empírica sólida para futuras investigaciones y programas educativos centrados en el desarrollo simultáneo de estas capacidades.

La **segunda fase** incluye dos estudios empíricos preliminares que dan respuesta al segundo y tercer objetivo. La muestra inicial consistió en 182 estudiantes con edades entre 12 y 16 años (M = 13,21, DT = 1,19). Entre ellos, 23 participantes presentaban necesidades específicas de apoyo educativo (NEAE): 5 con altas capacidades, 7 con TDAH, 7 con dislexia, 3 con discapacidad intelectual (DI) y 1 con Trastorno del Espectro del Autismo. Sin embargo, esta muestra inicial se ajusta en cada estudio en función de los objetivos específicos de la investigación y los criterios de inclusión. De esta manera, la muestra final de cada estudio varía para garantizar que los análisis sean adecuados a las características y variables específicas planteadas en cada estudio.

Para la evaluación de las capacidades cognitivas, se utilizaron diversos instrumentos. El pensamiento divergente se midió con la Prueba de Imaginación Creativa para Jóvenes (PIC-J), que incluye juegos para evaluar la creatividad verbal y gráfica. Las funciones ejecutivas se evaluaron utilizando el Nesplora Funciones Ejecutivas – Icecream, una herramienta de realidad virtual (RV) que simula un entorno multitarea realista y proporciona una medida ecología de las FE. Por último, la inteligencia se evaluó mediante la adaptación española del WISC-V, cubriendo los índices de comprensión verbal y razonamiento fluido.

El segundo objetivo se centró en examinar el desarrollo evolutivo de las FE y la creatividad a lo largo de la adolescencia, identificando los cambios significativos en estas capacidades y su interrelación. Para ello, el Estudio Publicado 2 fue clave.

Se realizaron análisis descriptivos y paramétricos con SPSS 27.0, incluyendo ANOVA y MANOVA para examinar la evolución de las FE y la creatividad y se llevó a cabo una regresión jerárquica en tres pasos para predecir la influencia de las variables sobre la inteligencia. Los resultados indicaron que, a lo largo de la adolescencia, ciertas FE, como la planificación y la memoria de trabajo, experimentan un desarrollo evolutivo significativo, mejorando progresivamente a medida que los adolescentes avanzan en su escolarización. En contraste, la creatividad, específicamente el pensamiento divergente, mostró un desarrollo más complejo. Los componentes de la creatividad verbal (fluidez, originalidad y elaboración) se mantuvieron relativamente estables, mientras que la creatividad figurativa (originalidad y detalles gráficos) disminuyó a medida que los adolescentes avanzaban en su educación.

Este hallazgo resalta la diferencia en la evolución de la creatividad según el tipo evaluado, sugiriendo que, aunque la creatividad verbal se desarrolla de manera continua, la creatividad figurativa puede estar más influenciada por factores contextuales y educativos. La

disminución de la creatividad figurativa podría reflejar el impacto de un entorno educativo que prioriza la precisión y la memoria sobre la originalidad y la expresión gráfica.

En conjunto, este estudio demostró que mientras las FE mejoran significativamente con la edad, la creatividad no sigue una trayectoria lineal, lo que subraya la necesidad de fomentar intervenciones educativas que atiendan tanto las FE como los diferentes tipos de creatividad.

El tercer objetivo, que fue comparar la creatividad y las FE en diferentes perfiles neurocognitivos, se exploró a través del Estudio Publicado 3. Este estudio investigó las diferencias en creatividad y FE entre adolescentes neurotípicos y neurodivergentes, incluidos estudiantes con TDAH, dislexia, DI y altas capacidades. Para ello, se aplicó un análisis multivariado de covarianza (MANCOVA), ajustando por edad y CI. Las diferencias entre grupos se analizaron con el test de comparaciones múltiples de Scheffé, y se calcularon tamaños del efecto según los criterios de Cohen (1988). Los resultados mostraron diferencias claras en creatividad y FE entre estos grupos. Por ejemplo, los adolescentes con TDAH destacaron en creatividad verbal, superando tanto a los neurotípicos como a los estudiantes con altas capacidades. Por otro lado, los estudiantes con DI obtuvieron las puntuaciones más bajas en creatividad verbal, mientras que los adolescentes con dislexia mostraron altos niveles de originalidad en creatividad figurativa. Estos hallazgos subrayan la necesidad de adaptar las evaluaciones y las intervenciones a los perfiles cognitivos específicos de los estudiantes, reconociendo tanto sus fortalezas como sus desafíos en creatividad y FE.

Finalmente, la **tercera fase** centrada en un análisis más profundo a través del análisis perfiles latentes para dar respuesta al objetivo 4 de esta Tesis Doctoral y que se centra en identificar distintos perfiles creativos en adolescentes, considerando factores como la neurodiversidad, el género y la inteligencia, con el fin de diseñar intervenciones educativas personalizadas (Estudio Complementario 1).

Para ello, se realiza análisis de perfiles latentes (LPA), con el software Mplus v.6.11, utilizando la muestra anteriormente mencionada. Se exploraron diferencias entre estos perfiles en relación con variables externas como el CI y la memoria de trabajo, utilizando estimación máxima de verosimilitud con error estándar robusto (MLR) para mayor precisión. A partir de lo análisis anteriores, se identifican tres perfiles creativos distintos entre los adolescentes, destacando que los perfiles con alta creatividad verbal tendían a incluir a estudiantes con necesidades educativas específicas (NEAE), lo que sugiere una relación entre la

neurodiversidad y la creatividad verbal. Aunque no se encontraron diferencias significativas en creatividad figurativa, estos resultados subrayan la importancia de reconocer la creatividad como una capacidad multifacética que se manifiesta de manera diferente en distintos contextos y perfiles neurocognitivos.

A lo largo de esta investigación, se ha demostrado que las FE y la creatividad están intrínsecamente relacionadas, pero de maneras complejas y dependientes del contexto. Las fases de la investigación han proporcionado una visión integral de cómo estas capacidades se desarrollan y manifiestan en diferentes momentos del ciclo vital y en distintos perfiles neurocognitivos.

Los hallazgos subrayan la importancia de enfoques educativos personalizados que fomenten tanto las FE como la creatividad en adolescentes, especialmente en aquellos con perfiles neurodivergentes. Además, la investigación sugiere que el desarrollo de la creatividad no es uniforme y que el tipo de creatividad (verbal o figurativa) puede estar influenciado por factores externos, como el entorno escolar y las expectativas sociales.

En resumen, esta Tesis Doctoral proporciona una base sólida para futuras investigaciones y prácticas educativas, destacando la importancia de una visión contextual y adaptada en el estudio de la creatividad y las FE en la adolescencia.

SUMMARY

Research on the relationship between creativity and executive functions (EF) in adolescents has gained momentum for understanding how these cognitive abilities interact during a key developmental period. Adolescence is a time when the brain undergoes significant changes that affect how young people process information, solve problems, and express creativity. In addition, EF, which include skills such as planning, working memory, cognitive flexibility, and inhibitory control, are critical for academic performance and adaptation to the demands of daily life. Given that creativity is considered a critical skill for success in today's world, understanding how these two domains are related can provide valuable insights into the design of educational interventions and personal development programs.

The main objective of this Doctoral Thesis has been to investigate how EF and creativity are related in adolescents, approaching this topic from different angles that allow not only to understand this relationship, but also to observe its evolution, variability according to the neurocognitive profile, and the identification of creative profiles. To address this objective, a methodological approach divided into three phases aligned with the following specific objectives is followed:

1. To analyze the relationship between EF and creativity in children and adolescents. From this initial review, we seek to map the main gaps in the literature and to inform the following studies. Published Study 1: *"Relationship between Executive Functions and Creativity in Children and Adolescents: A Systematic Review".*
2. To examine the evolutionary development of creativity and EFs throughout adolescence, analyzing changes and relationships throughout this transitional stage. This study explores how EF and creativity change over time as a function of age and other contextual factors. Published study 2: *"Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity".*
3. To compare creativity and EF in different neurocognitive profiles: neurotypical and neurodivergent adolescents. The analysis of the differences between these groups will allow us to identify how the trajectories of cognitive and creative development vary, and will provide valuable information for the design of inclusive interventions. Published Study 3: *"Neurodivergent Students. A Continuum of Skills with an Emphasis on Creativity and Executive Functions"***.**

4. To identify the existence of creative profiles in adolescents through an analysis of latent profiles, analyzing factors such as neurodiversity, gender, intelligence and age and exploring the implications of these profiles in their cognitive development. This objective will allow the identification of specific groups that may benefit from personalized educational interventions. Complementary Study 1: *"Latent Profile Analysis of Creativity: Relations with Intelligence and Executive Functions".*

The **first phase** consists of a systematic review of the literature with the aim of analyzing the relationship between EF and creativity in children and adolescents, assessing how these cognitive abilities interact and influence each other. This phase was developed through a systematic review of the existing scientific literature, embodied in Published Study 1. This systematic review revealed a significant relationship between certain EFs, in particular cognitive flexibility, and creativity. The ability to switch between different mental tasks or approaches proved to be a key predictor in the generation of creative responses, especially in the adolescent context. In addition, inhibitory control was found to have an inverse relationship with creativity; less inhibitory control may facilitate less conventional responses, increasing originality in the ideas generated.

The first objective of this research was to analyze the relationship between EF and creativity in children and adolescents, and to assess how these cognitive abilities interact and influence each other. This phase was developed through a systematic review of the existing scientific literature, embodied in Published Study 1. This systematic review revealed a significant relationship between certain EF, particularly cognitive flexibility, and creativity. The ability to switch between different mental tasks or approaches was found to be a key predictor in the generation of creative responses, especially in the adolescent context. In addition, inhibitory control was found to have an inverse relationship with creativity; less inhibitory control may facilitate less conventional responses, increasing the originality of the ideas generated.

On the other hand, the research showed that working memory was not directly related to creativity in this sample of adolescents. This finding is partly explained by the fact that the standard creativity tests used, such as the Torrance Test of Creative Thinking (TTCT), do not require a high working memory load. Similarly, it was found that adolescents with lower levels of attention tended to produce more original responses, suggesting that less focus may facilitate divergent thinking, a key to creativity.

This first phase concluded that EF, particularly flexibility and inhibitory control, play a critical role in adolescent creativity. Despite the variability in assessment instruments for both EF and creativity, these findings provide a solid empirical basis for future research and educational programs that focus on the simultaneous development of these skills.

The **second phase** includes two preliminary empirical studies that respond to the second and third objectives. The initial sample consisted of 182 students aged 12 to 16 years (M = 13.21, SD = 1.19). Among them, 23 participants had spcific educational support needs (SEN): 5 with high abilities, 7 with ADHD, 7 with dyslexia, 3 with intellectual disability and 1 with Autism Spectrum Disorder. However, this initial sample is adjusted in each study according to the specific objectives of the research and the inclusion criteria. Thus, the final sample of each study varies to ensure that the analyses are appropriate to the specific characteristics and variables proposed in each study.

Several instruments were used to assess cognitive abilities. Divergent thinking was measured with the Creative Imagination Test for Youth (PIC-J), which includes games to assess verbal and graphic creativity. Executive functions were assessed with the Nesplora Executive Functions - Icecream, a virtual reality tool that simulates a realistic multitasking environment and provides a measure of EF ecology. Finally, intelligence was assessed using the Spanish adaptation of the WISC-V, which includes indices of verbal comprehension and fluid reasoning.

The second goal was to examine the evolutionary development of EF and creativity throughout adolescence, identifying significant changes in these abilities and their interrelationships. For this purpose, the published Study 2 was key.

Descriptive and parametric analyses were conducted using SPSS 27.0, including ANOVA and MANOVA to examine the development of EF and creativity, and a three-level hierarchical regression to predict the influence of the variables on intelligence. The results indicated that during adolescence, certain EFs, such as planning and working memory, undergo significant evolutionary development, improving progressively as adolescents progress through schooling. In contrast, creativity, especially divergent thinking, showed a more complex development. The components of verbal creativity (fluency, originality, and elaboration) remained relatively stable, whereas figurative creativity (originality and graphic detail) declined as adolescents progressed through school.

This finding highlights the difference in the development of creativity according to the type assessed, suggesting that although verbal creativity develops continuously, figurative creativity may be more influenced by contextual and educational factors. The decline in figurative creativity may reflect the impact of an educational environment that prioritizes accuracy and memory over originality and graphic expression.

Overall, this phase demonstrated that while EF significantly improves with age, creativity does not follow a linear trajectory, underscoring the need to promote educational interventions that address both EF and different types of creativity.

Finally, the **third phase** focused on a deeper analysis through latent profile analysis to respond to objective 4 of this Doctoral Thesis, which focuses on identifying different creative profiles in adolescents, considering factors such as neurodiversity, gender and intelligence, in order to design personalized educational interventions (Complementary Study 1).

This study examined differences in creativity and EF between neurotypical and neurodivergent adolescents, including students with ADHD, dyslexia, intellectual disability, and giftedness. A multivariate analysis of covariance (MANCOVA) was used, adjusting for age and IQ. Differences between groups were analyzed using Scheffé's multiple comparison test, and effect sizes were calculated according to Cohen's criteria (1988). The results showed clear differences in creativity and EF between these groups. For example, adolescents with ADHD excelled in verbal creativity, outperforming both neurotypical and gifted students. On the other hand, students with intellectual disabilities scored lowest in verbal creativity, while adolescents with dyslexia showed high levels of originality in figurative creativity. These findings underscore the need to tailor assessments and interventions to students' specific cognitive profiles, recognizing both their strengths and challenges in creativity and EF.

In relation to phase 3, which focused on a deeper analysis through the analysis of latent profiles and the, it responds to objective 4 of this dissertation, resulting in one complementary study.

The fourth objective was to identify creative profiles in adolescents, taking into account factors such as neurodiversity, gender, intelligence and age. For this purpose, latent profile analysis (LPA) was performed with the software Mplus v.6.11, using the aforementioned sample. Differences between these profiles were examined in relation to external variables such as IQ and working memory, using maximum likelihood estimation with robust standard error (MLR) for greater precision. From the above analyses, three distinct creative profiles were

identified among adolescents, highlighting that profiles with high verbal creativity tended to include students with special educational needs (SEN), suggesting a relationship between neurodiversity and verbal creativity. Although no significant differences were found in figurative creativity, these results underline the importance of recognizing creativity as a multifaceted ability that manifests itself differently in different contexts and neurocognitive profiles.

Throughout this research, EF and creativity have been shown to be intrinsically related, but in complex and context-dependent ways. The research phases have provided a comprehensive view of how these capacities develop and manifest at different points in the life cycle and in different neurocognitive profiles.

The findings underscore the importance of personalized educational approaches that foster both EF and creativity in adolescents, especially those with neurodivergent profiles. Furthermore, the research suggests that the development of creativity is not uniform and that the type of creativity (verbal or figurative) may be influenced by external factors such as the school environment and social expectations.

In conclusion, this dissertation provides a solid foundation for future research and educational practice by highlighting the importance of a contextual and adaptive view in the study of creativity and EF in adolescence.

01

INTRODUCCIÓN

El estudio de la creatividad ha adquirido una relevancia creciente en las últimas décadas, al ser identificada como una de las habilidades fundamentales para el desarrollo de las sociedades del siglo XXI. Según el Foro de Economía Mundial y su agenda 2030, la creatividad figura entre las competencias clave, lo que refleja su importancia no solo en la innovación tecnológica y artística, sino también en la resolución de problemas complejos en diversos contextos profesionales y personales. En este sentido, la comunidad científica ha centrado esfuerzos en analizar los procesos subyacentes en la creatividad, especialmente en lo que respecta a su relación con el funcionamiento cognitivo.

La creatividad puede ser definida como la capacidad de generar ideas originales y útiles (Runco y Jaeger, 2012), y a menudo se mide a través de indicadores de pensamiento divergente, es decir la habilidad de producir múltiples soluciones a un problema (Runco y Acar, 2012). Este tipo de pensamiento está vinculado a procesos cognitivos complejos, entre los que destacan las Funciones Ejecutivas (FE). Las FE incluyen un conjunto de habilidades cognitivas de alto nivel, como la memoria de trabajo, la flexibilidad cognitiva o el control inhibitorio (Miyake et al., 2000), que permiten a los individuos regular su comportamiento, planificar, tomar decisiones y adaptarse a situaciones nuevas. Estas FE son fundamentales en contextos como el aprendizaje, donde influyen en la capacidad de organizar información, gestionar el tiempo y abordar tareas escolares complejas (Best et al., 2011). Asimismo, las FE son cruciales en la resolución de conflictos y la toma de decisiones en las relaciones sociales, facilitando la regulación emocional y el comportamiento prosocial (Zelazo et al., 2016). Las FE no solo impactan el rendimiento académico, sino que también son predictoras de éxito en otras áreas del desarrollo infantil y adolescente, como la creatividad, la regulación emocional y el desarrollo social (Benedek et al., 2014; Carlson et al., 2013).

¿Qué se ha investigado?

Esta Tesis Doctoral aborda el análisis de la creatividad y los procesos cognitivos con los que se relaciona en una muestra de adolescentes (12-16 años). A través de esta investigación se explora la interrelación entre la creatividad, medida principalmente como pensamiento divergente, y las FE, medida con una herramienta de RV. Este enfoque innovador permite una medición dinámica y ecológicamente válida de las capacidades cognitivas. Para ello se consideran tanto poblaciones neurotípicas como neurodivergentes, lo que permite una comparación integral entre distintos grupos, con el fin de identificar diferencias en los perfiles creativos.

El objetivo central es, por tanto, analizar cómo se puede medir la creatividad y las FE, así como investigar cómo ambas capacidades se interrelacionan y evolucionan durante este período crítico de desarrollo. Asimismo, se pretende identificar y caracterizar distintos perfiles creativos en adolescentes, teniendo en cuenta la influencia de otras variables como la neurodiversidad, el género, la edad y la inteligencia. A través de una combinación de metodologías cuantitativas, que incluyen revisión sistemática mediante metodología PRISMA, análisis de perfiles latentes y modelos estadísticos avanzados para los estudios empíricos, esta Tesis Doctoral aspira a proporcionar una comprensión profunda de los factores que influyen en el desarrollo creativo y cognitivo, y cómo estos pueden ser modulados a través de intervenciones educativas específicas.

¿Por qué se ha llevado a cabo?

Esta investigación es relevante por diversas razones, que abarcan los ámbitos **social**, **académico** y **científico**.

1. **A nivel social.** La adolescencia es una etapa crítica en el desarrollo del individuo, marcada por cambios neurobiológicos significativos y la maduración de las FE, la creatividad y la inteligencia. Durante esta etapa, las FE, experimentan un rápido desarrollo, lo que influye directamente en la capacidad de los adolescentes para regular su comportamiento. Por otro lado, la creatividad, también se encuentra en un proceso de evolución durante este periodo. Comprender la relación entre las FE y la creatividad en la adolescencia puede tener implicaciones directas en el diseño de programas educativos e intervenciones psicoeducativas orientadas a potenciar el rendimiento académico y el bienestar socioemocional de los adolescentes.

   Además, en el contexto de la neurodiversidad, es fundamental desarrollar estrategias inclusivas que consideren las particularidades cognitivas de individuos neurodivergentes (por ejemplo, aquellos con Trastorno por Déficit de Atención e Hiperactividad (TDAH) o altas capacidades), lo cual permitirá crear entornos de aprendizaje más equitativos. Los resultados de esta investigación podrían informar la creación de programas pedagógicos personalizados, ajustados a los perfiles cognitivos y creativos de los estudiantes, lo que contribuiría a una educación más efectiva y adaptada a las necesidades de cada adolescente.

2. **A nivel académico:** En las últimas décadas, ha habido un aumento significativo del interés académico por el estudio de las FE y la creatividad en la adolescencia, dada la interrelación entre el desarrollo cognitivo y el rendimiento académico, así como su

influencia en la resolución de problemas complejos y la toma de decisiones en la vida diaria. Sin embargo, a pesar de este interés, la intersección entre la creatividad y las FE, especialmente en poblaciones neurotípicas y neurodivergentes, sigue siendo un área que requiere mayor exploración. Mientras que algunos estudios han examinado las FE y la creatividad de manera aislada, son escasos aquellos que han investigado su relación en profundidad durante la adolescencia, un periodo en el que ambos procesos se encuentran en una fase de desarrollo crítico.

Este trabajo se propone llenar ese vacío en la literatura, contribuyendo al avance del conocimiento sobre cómo las FE y la creatividad se desarrollan y se influencian mutuamente a lo largo de la adolescencia. Asimismo, el uso de herramientas innovadoras, como la RV para la medición de las FE, y la aplicación de análisis de perfiles latentes y metodologías avanzadas, permiten un enfoque multidimensional y preciso que puede abrir nuevas vías para la investigación académica en este campo.

3. **A nivel científico:** Desde una perspectiva científica, los resultados de esta investigación podrían tener importantes implicaciones para la comprensión del desarrollo cognitivo y creativo en las etapas infantiles y adolescentes. El desarrollo de las FE está vinculado a procesos de maduración cortical que se prolongan hasta la adultez temprana, y la creatividad, en su vertiente de pensamiento divergente, está influenciada tanto por factores neurológicos como por el contexto socioambiental. Este estudio puede proporcionar evidencia empírica sobre cómo ambos procesos interactúan durante la adolescencia y si existen diferencias significativas en función de la neurodiversidad, el género, la inteligencia y otros factores individuales.

   Por otro lado, los hallazgos de esta investigación podrían contribuir al desarrollo de nuevas teorías sobre el desarrollo cognitivo, proporcionando una base para modelos más integradores que aborden la creatividad no solo como un proceso aislado, sino como parte de un conjunto de habilidades cognitivas interrelacionadas. Además, los resultados pueden arrojar luz sobre posibles mecanismos subyacentes que expliquen cómo se pueden potenciar tanto las FE como la creatividad mediante intervenciones dirigidas, con implicaciones para la neuroeducación, la psicología del desarrollo y la pedagogía. Este enfoque multidisciplinar es fundamental para avanzar hacia una comprensión más holística del desarrollo humano.

A continuación, y para contextualizar adecuadamente la presente Tesis Doctoral, es fundamental establecer un marco teórico sólido que sustente la investigación de la relación entre las FE y la creatividad en adolescentes. Para ello, se expone una revisión exhaustiva de la literatura relevante, que abordará los principales modelos teóricos sobre las FE, su desarrollo durante la adolescencia, y su vinculación con la creatividad. Asimismo, se examinarán estudios previos que han investigado estas variables en poblaciones neurotípicas y neurodivergentes, con el fin de identificar lagunas en la investigación actual y justificar la relevancia del presente trabajo. Esta base teórica proporciona el fundamento necesario para comprender en profundidad el enfoque metodológico y los objetivos específicos que guían las fases empíricas del estudio.

02

MARCO TEÓRICO

CREATIVIDAD Y FUNCIONES EJECUTIVAS

La adolescencia es una etapa crucial del desarrollo humano y que está caracterizada por importantes cambios cognitivos, emocionales y sociales (Dahl et al., 2018). Dos variables fundamentales que emergen y se consolidan durante este período son la creatividad y las FE (Crone et al., 2017; Kleibeuker et al., 2016). La creatividad, entendida como la capacidad de generar ideas nuevas y originales, y de aplicarlas de manera práctica y que se manifiesta principalmente a través del pensamiento divergente (Runco y Jaeger, 2012). Este tipo de pensamiento es esencial para la resolución de problemas y la innovación, aspectos clave en el aprendizaje y el desarrollo personal.

Por otro lado, las FE representan un conjunto de habilidades cognitivas que incluyen la planificación, la memoria de trabajo, la flexibilidad cognitiva y la inhibición, entre otras (Miyake et al., 2000). Estas habilidades son esenciales para el manejo de tareas complejas y la adaptación a diferentes contextos educativos y sociales. En la evaluación de las FE, la RV ha emergido como una herramienta innovadora, proporcionando entornos simulados que permiten una valoración más ecológica de estas capacidades (Borgnis et al., 2022)

La relación entre la creatividad y las FE es un campo de estudio que ha recibido creciente atención en los últimos años. Investigaciones recientes (Krumm et al., 2018; Palmiero et al., 2022) sugieren que estas dos variables están interconectadas, y su desarrollo conjunto puede influir significativamente en el rendimiento académico y el bienestar emocional de los adolescentes. Comprender cómo se desarrollan y cómo interactúan la creatividad y las FE a lo largo del tiempo es crucial para diseñar intervenciones educativas efectivas.

Además, la adolescencia es un periodo de gran variabilidad en cuanto a los perfiles individuales de desarrollo. Los estudiantes presentan diferencias significativas no solo en términos de habilidades cognitivas generales, sino también en términos de neurodiversidad. Condiciones como el TDAH, la dislexia, la DI y las altas capacidades son ejemplos de neurodivergencia que pueden influir en el desarrollo de la creatividad y las FE.

Una perspectiva neurodiversa reconoce que estas diferencias no son deficiencias, sino variaciones naturales del desarrollo humano que requieren enfoques educativos personalizados (McGee, 2012). Al considerar variables como la inteligencia, las necesidades educativas específicas, el género y la edad, se pueden identificar los factores que influyen en la relación entre la creatividad y las FE, permitiendo así una comprensión más profunda y holística de estos procesos.

En este marco teórico, se explorarán detalladamente la creatividad y su medida como pensamiento divergente, las FE y su evaluación con RV, así como la relación entre estas dos variables anteriormente mencionadas. Seguidamente se profundizará en el desarrollo evolutivo de la creatividad y las FE, los perfiles creativos y de FE en la adolescencia, así como la perspectiva neurodiversa de la creatividad y las FE y las variables que influyen en la relación entre la creatividad y las funciones ejecutivas, incluyendo aquí la inteligencia, las necesidades educativas, el género y la edad. Este análisis permitirá una comprensión integral de cómo estas variables interactúan y se desarrollan en la adolescencia, proporcionando una base sólida para futuras investigaciones e intervenciones educativas.

2.1. LA CREATIVIDAD Y SU MEDIDA COMO PENSAMIENTO DIVERGENTE

La creatividad es la capacidad de generar ideas nuevas y originales que sean útiles y apropiadas para cada situación (Plucker y Makel, 2010; Runco y Jaeger, 2012). Este concepto ha sido ampliamente estudiado y teorizado por diversos autores y enfoques. Guilford (1967) introdujo la distinción entre pensamiento convergente y divergente, destacando este último como esencial para la creatividad. Amabile (1983) propuso que la creatividad es el resultado de la interacción entre tres componentes: habilidades relacionadas con el dominio, habilidades de pensamiento creativo y motivación intrínseca. Lubart y Sternberg (1995) desarrollaron la teoría de la inversión, sugiriendo que las personas creativas "compran bajo y venden alto" en el mundo de las ideas, es decir, buscan ideas inusuales que luego desarrollan y presentan cuando son aceptadas. Por último, Csikszentmihalyi (1997) introdujo el concepto de "flujo", un estado de concentración plena y disfrute en el proceso creativo.

La creatividad es fundamental en los contextos educativos y sociales debido a su impacto significativo en el desarrollo personal y profesional. En el ámbito educativo, la creatividad facilita un aprendizaje más profundo y significativo. Wechsler et al. (2018) y Martz et al. (2017) argumentan que la creatividad es importante en la educación ya que fomenta el pensamiento crítico y la resolución de problemas. Además, Beghetto y Kaufman (2007) destacan que la creatividad en el aula ayuda a los estudiantes a conectar conocimientos de diferentes disciplinas, promoviendo una comprensión más holística y aplicable del mundo.

En contextos sociales, la creatividad es esencial para la innovación y el progreso. Florida (2012) señala que las economías modernas prosperan gracias a la creatividad y la innovación, y que las ciudades con una alta concentración de personas creativas tienden a ser más dinámicas y exitosas. Además, la creatividad promueve la adaptación y la resiliencia en

tiempos de cambio, como lo destaca Sternberg (2006), quien sostiene que la capacidad creativa permite a las personas encontrar soluciones novedosas a los desafíos contemporáneos.

En cuanto al desarrollo personal y profesional, la creatividad contribuye a la satisfacción y el bienestar. Csikszentmihalyi (1997) introduce el concepto de "flujo", un estado de concentración y disfrute pleno en el proceso creativo, que está asociado con una mayor felicidad y realización personal. En términos profesionales, Mumford (2000) argumenta que la creatividad es crucial para la resolución de problemas complejos y la toma de decisiones efectivas, habilidades altamente valoradas en cualquier campo.

Al hablar de creatividad es inevitable mencionar la disyuntiva entre pensamiento divergente y convergente. Entendiendo el pensamiento convergente como aquel que busca una única solución correcta a un problema (de Vries y Lubart, 2019) y entendiendo que el pensamiento divergente es el que más cerca está de la concepción de creatividad que defienden autores como Guilford (1967) definiéndolo como un proceso mental que implica generar ideas variadas y numerosas.

Tabla 1.

Componentes de la creatividad

Fluidez	Capacidad de generar muchas ideas y que es un componente crucial para tener una amplia gama de soluciones al resolver un problema. Según Torrance (1998) una alta fluidez correlaciona con una mayor creatividad.
Flexibilidad	Capacidad de generar ideas variadas. Guilford (1967) destacó que la flexibilidad permite cambiar de perspectiva y abordar problemas desde diferentes ángulos.
Originalidad	Capacidad de generar ideas únicas o inusuales y es lo que distingue las ideas verdaderamente creativas de las convencionales. Mednick (1967) introdujo la teoría de la asociación remota, sugiriendo que las ideas originales surgen de la conexión entre conceptos distantes.
Elaboración	Capacidad de desarrollar y enriquecer ideas. Este componente implica agregar detalles y profundizar en las ideas iniciales para hacerlas más completas y aplicables. Torrance (1998) incluyó la elaboración como un criterio importante en sus pruebas de creatividad.

Elaboración propia

Por otro lado, Torrance (1998), conocido por sus pruebas de pensamiento creativo (TTCT), también subrayó la relevancia del pensamiento divergente, identificando componentes clave que lo caracterizan como la fluidez, la flexibilidad, la originalidad y la elaboración que se presentan en la Tabla 1.

Pero, ¿Cómo se mide el pensamiento divergente?

La evaluación de la creatividad ha sido un desafío complejo para los investigadores debido a la naturaleza multifacética y subjetiva del concepto (Runco y Jagger, 2012). Existen diversas medidas para evaluar la creatividad, abarcando desde pruebas psicométricas hasta evaluaciones subjetivas y cualitativas. Sin embargo, el pensamiento divergente, definido como la capacidad de generar múltiples soluciones o ideas novedosas ante un problema, es considerado el indicador más directo del potencial creativo, ya que captura la flexibilidad y originalidad del proceso creativo (Runco y Yoruk, 2014). Entre las pruebas más reconocidas para medir el pensamiento divergente, se destacan el Test de Pensamiento Creativo de Torrance (TTCT; Torrance, 1998) y el Test de Usos Alternativo (AUT; Guilford et al., 1978). Estas pruebas han sido fundamentales para comprender las capacidades creativas en distintos contextos, ya que permiten evaluar componentes clave del pensamiento divergente como la fluidez, flexibilidad, originalidad y elaboración.

Por un lado, el Test de Pensamiento Creativo de Torrance (TTCT; Torrance, 1998) es una de las pruebas más utilizadas y reconocidas para medir el pensamiento divergente y divide en dos formas que se relacionan con el tipo de creatividad a medir. Estos procesos de creatividad verbal y figural están relacionados en el sentido de que ambos pueden basarse en procesos implicados en el pensamiento divergente (Benedek y Fink, 2019), tal y como se muestra en la Tabla 2.

Tabla 2.

Formas de medir el pensamiento divergente

Forma verbal	Implica la expresión verbal y la comunicación. Se puede medir a través de tareas como preguntar y adivinar consecuencias, mejorar productos, y situaciones extraordinarias.
Forma figurativa	Se centra en la representación visual o espacial. Se puede medir a través de tareas de dibujo, como completar figuras parciales, crear imágenes a partir de formas abstractas, y construir escenas.

Elaboración propia (Goff y Torrance, 2002)

Por otro lado, el Test de Usos Alternativos (AUT; Guilford et al., 1978) es otra herramienta muy utilizada para medir el pensamiento divergente. En esta prueba, se pide a los participantes que enumeren tantos usos alternativos como puedan para un objeto común, como un ladrillo o un clip, en un tiempo determinado.

Pero también es importante comprender cómo se puntúan o analizan estos componentes o pruebas creativas a través de diferentes métodos de puntuación y análisis. Los más comunes incluyen:

- **Puntuación holística**. en la que se da una evaluación general de la creatividad medida con las respuestas, pero sin desglosar en componentes específicos.
- **Puntuación analítica**, en la que se da evaluación detallada de cada componente (fluidez, flexibilidad, originalidad, elaboración) por separado.
- **Métodos estadísticos**, en los que se utilizan análisis estadísticos para interpretar los resultados, identificar patrones y comparar las puntuaciones con normas establecidas.

El uso de estos instrumentos y métodos permite una evaluación integral del pensamiento divergente, proporcionando una comprensión profunda de las capacidades creativas de los individuos. Pero también existen limitaciones en estas pruebas en torno a la validez, el sesgo cultural y contextual y la diversidad de pruebas existentes.

Por un lado, existe un debate abierto sobre la validez, entendida como la capacidad de una prueba para medir lo que se propone medir. Estudios como los de Kaufman y Baer (2012) y Baer (2017) se cuestionan si las pruebas de pensamiento divergente pueden predecir el éxito creativo en contextos de la vida real, ya que estas pruebas miden la capacidad de generar ideas, no necesariamente la aplicación efectiva de la creatividad en situaciones prácticas.

Por otro lado, la creatividad es un constructo complejo que puede manifestarse de manera diferente según el contexto cultural (Cohen, 2012; Helfand et al., 2016) Las pruebas de pensamiento divergente a menudo no tienen en cuenta estas diferencias, lo que puede llevar a una evaluación sesgada. Autores como Erez y Nouri (2010) y Sawyer (2017) aseguran que los resultados de las pruebas pueden estar influenciados por las normas y valores culturales predominantes, lo que puede afectar el rendimiento de individuos de diferentes orígenes culturales. Además, las oportunidades para desarrollar y expresar creatividad varían considerablemente entre diferentes entornos educativos y sociales (Nouri et al., 2015).

Por último, las pruebas de pensamiento divergente tienden a enfocarse en ciertos tipos de tareas, lo que puede limitar la comprensión completa de la creatividad de un individuo. Muchas pruebas de pensamiento divergente, como el TTCT (Torrance, 1998), se centran en la capacidad de generar muchas ideas (fluidez) y en la originalidad de las mismas. Sin embargo, la creatividad también incluye la capacidad de desarrollar y enriquecer ideas (elaboración) y la flexibilidad para cambiar de enfoque. La falta de diversidad en las tareas evaluadas puede ofrecer una visión incompleta de las habilidades creativas (Runco y Acar, 2012). Además, la creatividad puede variar considerablemente dependiendo del estado emocional del individuo, la motivación y el contexto en el que se realiza la prueba (Soroa et al., 2015).

Estas limitaciones asociadas con la medición del pensamiento divergente subrayan la necesidad de un enfoque más holístico y contextualizado en la evaluación de la creatividad. Por ello, es fundamental desarrollar pruebas que sean culturalmente sensibles, que evalúen una gama más amplia de habilidades creativas y que consideren el contexto en el que se realiza la evaluación. Solo así se podrá obtener una comprensión más precisa y completa de la creatividad y su aplicación en la vida real.

2.2. LAS FUNCIONES EJECUTIVAS Y SU EVALUACIÓN CON REALIDAD VIRTUAL

Las funciones ejecutivas (FE) son un conjunto de habilidades cognitivas superiores que ayudan a controlar pensamientos, comportamientos y emociones (Diamond, 2013). Estas habilidades permiten a los individuos planificar, tomar decisiones, resolver problemas, controlar impulsos y adaptarse a nuevas situaciones (Lezak, 2004). Las FE incluyen componentes clave como la memoria de trabajo, la planificación y la flexibilidad cognitiva (Diamond, 2013) y son habilidades esenciales para el desarrollo académico, social y personal (Luna et al., 2010).

Varios autores y teorías han contribuido significativamente a la comprensión de las FE. Luria (1966) fue uno de los primeros en describir las FE en el contexto de la neuropsicología, señalando su papel crucial en el comportamiento dirigido a metas. Baddeley y Hitch (1974) introdujeron el modelo de memoria de trabajo, destacando su importancia en el procesamiento y manipulación de información. Más recientemente, Miyake et al. (2000) propusieron un modelo de funciones ejecutivas que incluye tres componentes principales: memoria de trabajo, control inhibitorio y flexibilidad cognitiva. Posteriormente Diamond (2013) amplió estos modelos al subrayar la interdependencia de estos componentes y cómo su desarrollo es esencial para el éxito en la vida académica y social.

Las FE han sido clasificadas de diversas maneras por distintos autores a lo largo del tiempo, reflejando la complejidad y la perspectiva multifacética de estas habilidades cognitivas. Miyake et al. (2000) propusieron un modelo que identifica tres componentes principales: memoria de trabajo, control inhibitorio y flexibilidad cognitiva. Este modelo ha sido muy importante para comprender cómo estas se interrelacionan y contribuyen al comportamiento dirigido a un objetivo. Anderson (2010) sugirió una categorización que incluye la organización y la secuenciación de tareas, además del control emocional, destacando la importancia de las FE en la regulación de emociones y comportamientos. Por último, Diamond (2013) amplió esta clasificación al incluir la capacidad de planificación y el razonamiento de la tarea, enfatizando cómo estas funciones se desarrollan y se refinan a lo largo de la vida, influyendo en el éxito académico y social. Estas clasificaciones reflejan la diversidad y la interdependencia de las FE, esenciales para el funcionamiento cognitivo y el desempeño eficaz en la vida diaria.

A lo largo de este trabajo se profundizará en el estudio de tres FE que son definidas en la Tabla 3:

Tabla 3.

Definición de las tres funciones ejecutivas

Memoria de trabajo	Capacidad de mantener y manipular información temporalmente para realizar tareas cognitivas complejas. Esta habilidad es crucial para el aprendizaje, la comprensión y la resolución de problemas (Baddeley, 2006)
Planificación	Capacidad de controlar impulsos y respuestas automáticas, anticipar consecuencias y desarrollar estrategias efectivas para organizar y ejecutar una secuencia de acciones dirigidas a un objetivo (Anderson, 2010).
Flexibilidad cognitiva	Capacidad de adaptarse a nuevas situaciones y cambiar de estrategia cuando las circunstancias cambian (Diamond, 2013).

Elaboración propia

La evaluación de las FE ha sido tradicionalmente realizada mediante pruebas neuropsicológicas estandarizadas. Algunas de las más utilizadas incluyen el Stroop test (Golden, 1978; Stroop, 1935) que evalúa el control inhibitorio y la capacidad de resistir interferencias; la Torre de Hanoi (Welsh y Huizinga, 2001) que mide la capacidad de planificación y resolución de problemas; o el Wisconsin Card Sorting Test (WCST; Heaton, 1981) que valora la flexibilidad cognitiva y la capacidad de cambiar de estrategia en respuesta a reglas cambiantes.

Sin embargo, en los últimos años ha surgido un creciente interés por el uso de la RV como herramienta para evaluar estas habilidades (Borgnis et al., 2022), ya que los métodos tradicionales, a menudo, carecen de ecología, es decir, no reflejan la complejidad y dinamismo de las situaciones cotidianas. La RV permite crear entornos más inmersivos, realistas e interactivos que pueden ser utilizados para evaluar diferentes aspectos de las FE, como la planificación, la toma de decisiones, la resolución de problemas y la flexibilidad cognitiva (Jansari et al., 2014).

Tabla 4.

Pruebas de funciones ejecutivas con realidad verbal

Virtual Environment Grocery Store (VEGS)	Parsons y McMahan (2017) Simula una tienda de alimentos donde los participantes deben realizar una serie de tareas como planificar y seguir una lista de compras, encontrar productos en los estantes y manejar cambios en el entorno. Con ello, se evalúan FE como la memoria de trabajo, la planificación y la flexibilidad cognitiva.
Virtual Supermarket Environment	Nir-Hadad et al. (2017) Experiencia inmersiva en un supermercado donde los participantes deben realizar compras siguiendo instrucciones específicas, gestionando un presupuesto y adaptándose a cambios en las tareas. Con ello se evalúa la planificación, la organización y la toma de decisiones en un contexto de compras.
Nesplora Aquarium	Climent et al. (2021) Simula un acuario interactivo donde los participantes deben realizar tareas que implican atención sostenida, memoria de trabajo y control inhibitorio.
Nesplora Ice-Cream	Fernández et al. (2023) Simula una heladería donde los participantes deben gestionar pedidos de clientes, controlar inventarios y responder a situaciones imprevistas con el objetivo de evaluar la planificación, la organización y la flexibilidad cognitiva.

Elaboración propia

Para ello, existen diferentes herramientas y aplicaciones de RV diseñadas específicamente para evaluar las FE. Por ejemplo, se encuentran herramientas como *Virtual Environment Grocery Store* (VEGS) de Parsons y MacMahan (2017); *Virtual Supermarket*

Environment (Nir-Hadad et al., 2017) o las creadas por Nesplora: *Nesplora Aquarium* (Climent et al. 2021) y *Nesplora Ice-Cream* (Fernández et al., 2023) y que se recogen en la Tabla 4.

La incorporación de la RV en la evaluación e intervención de las FE en contextos educativos y clínicos ofrece una serie de ventajas significativas, como mejorar la identificación temprana de estudiantes con dificultades en FE permitiendo intervenciones oportunas. Por ejemplo, programas como Nesplora Aula permiten evaluar la atención y la memoria de trabajo en un entorno de aula virtual, identificando problemas que pueden no ser evidentes en pruebas tradicionales (Areces et al., 2018).

Pero el uso de RV también presenta ciertas limitaciones que deben considerarse. Por un lado, las evaluaciones basadas en RV requieren equipos especializados y un mantenimiento regular que incluya actualizaciones de software para funcionar correctamente (Parsons, 2015). Además, pueden encontrarse dificultades de adaptabilidad del usuario, quienes pueden experimentar malestar o mareos durante el uso, lo que puede limitar la participación y la duración, afectando los resultados obtenidos (Bohil et al., 2011). Por último, aunque los entornos de RV pueden simular situaciones cotidianas, no siempre replican de manera precisa todos los aspectos de la vida real. La capacidad de los resultados obtenidos en entornos virtuales para generalizarse a comportamientos y competencias en el mundo real puede ser limitada y pueden no representar adecuadamente las situaciones específicas o contextos individuales de cada usuario, lo que puede afectar la validez ecológica de las evaluaciones (Knight y Titov, 2009).

A pesar de las limitaciones mencionadas, la RV sigue pareciendo una herramienta prometedora para la evaluación de las FE. Es importante abordar estos desafíos mediante investigaciones continuas que permitan maximizar el potencial de la RV para ofrecer evaluaciones precisas y contextualmente relevantes.

2.3. DESARROLLO EVOLUTIVO DE LA CREATIVIDAD Y LAS FUNCIONES EJECUTIVAS

Entender cómo evolucionan la creatividad y las FE a lo largo del desarrollo humano es fundamental para comprender la adaptación y el aprendizaje a lo largo de la vida. Estas habilidades cognitivas y ejecutivas desempeñan un papel esencial en la capacidad de los individuos para enfrentar desafíos, resolver problemas y adaptarse a nuevos entornos (Cohen, 2012; Koziol y Lutz, 2013).

Por un lado, la creatividad evoluciona significativamente desde la infancia hasta la adultez. Durante la infancia, los niños muestran una gran capacidad para la imaginación y la generación de ideas originales, aunque estas ideas a menudo carecen de estructura y aplicación práctica. A medida que los individuos crecen, su creatividad se refina y se vuelve más estructurada y dirigida a metas específicas (Hui et al., 2019).

Por otro lado, las FE también muestran un desarrollo significativo desde la infancia temprana hasta la adolescencia. Estos procesos cognitivos se desarrollan de manera escalonada, con hitos importantes que marcan el progreso en la memoria de trabajo, el control inhibitorio, la flexibilidad cognitiva y la planificación (Taylor et al., 2013).

Durante la infancia, los niños comienzan a desarrollar la memoria de trabajo y el control inhibitorio. Estas habilidades son básicas pero fundamentales, permitiendo a los niños seguir instrucciones simples y controlar impulsos inmediatos. Durante la adolescencia, todas las FE continúan refinándose y la flexibilidad comienza a ser más importante, teniendo la memoria de trabajo y el control inhibitorio como mediadores (Karr et al., 2022).

El desarrollo evolutivo de la creatividad y las FE es un proceso complejo y continuo que juega un papel fundamental en la adaptación y el aprendizaje a lo largo de la vida. Comprender cómo estas habilidades se desarrollan desde la infancia hasta la adolescencia proporciona una base sólida para diseñar intervenciones educativas y terapéuticas que promuevan un desarrollo cognitivo saludable y eficiente. Así como entender la relación entre estas dos variables ofrecerá información de valor para estas intervenciones.

2.4. LA RELACIÓN ENTRE LA CREATIVIDAD Y LAS FUNCIONES EJECUTIVAS

La relación entre las FE y la creatividad es un tema de investigación relativamente reciente. Tradicionalmente, la creatividad y las FE se han estudiado de manera independiente. La investigación sobre creatividad ha enfatizado la generación de ideas originales y útiles, principalmente en el contexto de las artes y la innovación (Sternberg, 2006). Por otro lado, el estudio de las FE se ha centrado en el control inhibitorio, la memoria de trabajo o la flexibilidad cognitiva y su relación con otras variables como la regulación emocional y el rendimiento académico (Diamond, 2013; Goldstein y Naglieri, 2014; Miyake et al., 2000). Sin embargo, la creciente complejidad del entorno actual requiere una comprensión integrada de cómo estas dos áreas se relacionan y se potencian mutuamente para influir en el pensamiento innovador y la adaptación (Zabelina et al., 2019).

En los últimos años, se ha producido un creciente interés por comprender la relación entre las FE y la creatividad en la infancia y la adolescencia (Krumm et al., 2018; Stolte et al., 2020). Varios estudios han investigado cómo las FE pueden tanto facilitar como limitar la creatividad. Por ejemplo, Diamond (2013) sugiere que una buena memoria de trabajo puede ayudar a mantener y manipular múltiples ideas creativas simultáneamente. Sin embargo, Benedek et al. (2014) afirma que el control inhibitorio excesivo podría suprimir ideas inusuales, limitando la expresión creativa. Por otro lado, otros estudios han mostrado que la flexibilidad cognitiva, una FE clave, es esencial para la generación de ideas diversas y la adaptación a nuevas situaciones (De Dreu et al., 2012).

Sin embargo, la relación entre las FE y la creatividad no es simple y directa. Pueden existir otros factores que también jugarían un papel importante en la creatividad, como la inteligencia, la motivación y el tipo de metodología utilizada (Denervaud et al., 2019; Krumm et al., 2018; Kvintova et al., 2022).

Pero esta relación no se puede hacer solamente de variable a variable, también se puede tener en cuenta los perfiles creativos de los estudiantes para explorar su relación con el desarrollo de las FE.

2.5. PERFILES CREATIVOS Y SU RELACIÓN CON LAS FUNCIONES EJECUTIVAS EN LA ADOLESCENCIA

Comprender los perfiles individuales de creatividad puede jugar un papel fundamental, ya que estas etapas de desarrollo están marcadas por significativos cambios cognitivos, emocionales y sociales (Scott y Saginak, 2016). La creatividad en la adolescencia no solo es un indicador del potencial innovador, sino que también está relacionada con el bienestar emocional y la adaptación social (Kaufman y Baer, 2012). Evaluar y apoyar estos perfiles creativos puede contribuir a fomentar talentos y habilidades que son esenciales para el desarrollo integral de los jóvenes.

El perfil creativo se refiere a un conjunto de características y habilidades específicas que determinan cómo un individuo genera y desarrolla ideas nuevas y originales. Este perfil puede ser evaluado a través de diferentes dimensiones de la creatividad, como la fluidez, la flexibilidad, la originalidad y la elaboración (Guilford, 1967; Torrance, 1998). Estos perfiles creativos pueden variar considerablemente entre los adolescentes. Por ejemplo, algunos pueden destacar en la fluidez, generando una gran cantidad de ideas en poco tiempo, mientras que otros pueden ser más fuertes en la originalidad, produciendo ideas que son verdaderamente únicas y

poco comunes (Torrance, 1998). Estos componentes interactúan y se manifiestan de manera diversa en cada individuo, formando perfiles únicos de creatividad.

Además, diversos factores pueden influir en estos perfiles creativos, incluyendo el desarrollo de sus FE. Las FE, que incluyen la memoria de trabajo, la planificación y la flexibilidad cognitiva, permiten a los adolescentes gestionar y manipular información, inhibir respuestas inapropiadas y adaptarse a nuevas situaciones, habilidades importantes para el desarrollo de la creatividad (Benedek et al., 2014; Vartanian, 2021)

Estos perfiles creativos pueden estar influenciados por varios factores, como la edad, el género, la inteligencia y las necesidades específicas de apoyo educativo (NEAE). La edad y la maduración cognitiva juegan un papel significativo en el desarrollo de las FE y la creatividad (Barbot y Heuser, 2017; Best y Miller, 2010). Otros estudios (Abraham, 2016; Baer y Kaufman, 2008) han encontrado diferencias de género en la expresión creativa, con niñas y niños mostrando fortalezas en diferentes áreas de la creatividad. La inteligencia también está correlacionada con la creatividad, aunque no son sinónimos, ya que la creatividad implica más que solo habilidades cognitivas (Plucker et al., 2015). Las NEAE, como el TDAH y la dislexia, pueden influir en cómo se manifiestan las FE y la creatividad, presentando tanto desafíos como oportunidades únicas para el desarrollo creativo (Girard-Joyal y Gauthier, 2022; Majeed et al., 2021).

Existen investigaciones que analizan perfiles de FE en relación con la creatividad. Investigaciones como la de Lin y Lien (2013) analizan los perfiles de memoria de trabajo y muestran que una menor memoria de trabajo verbal puede estar asociada a puntuaciones más altas en DT. Del mismo modo, de Vink et al. (2023) analizaron perfiles de memoria de trabajo con DT e indicaron que una buena memoria de trabajo visual puede facilitar el DT visual, mientras que el DT verbal puede depender de variables más distribuidas.

Una comprensión integral de los perfiles individuales de creatividad y su relación con las otras variables no solo permite identificar y fomentar el potencial creativo en los jóvenes, sino que también proporciona una base sólida para diseñar intervenciones educativas y psicológicas que promuevan el desarrollo personal y académico. Al reconocer las diversas maneras en que los adolescentes expresan su creatividad es posible crear entornos que valoren y nutran estas diferencias, facilitando así un crecimiento equilibrado y holístico. Sin olvidar la importancia de una perspectiva neurodiversa y comprensiva de la creatividad y las FE, tal y como se muestra a continuación.

2.6. PERSPECTIVA INCLUSIVA DE LA CREATIVIDAD Y LAS FUNCIONES EJECUTIVAS

Adoptar una perspectiva neurodiversa en el estudio de la creatividad y las FE podría ser útil para una comprensión más completa e inclusiva de estas habilidades. La neurodiversidad es un enfoque que reconoce la variabilidad natural en el funcionamiento neurológico, considerando las diferencias entre los cerebros humanos no como "déficits", sino como parte de la diversidad cognitiva y neurológica inherente a nuestra especie (Griffiths, 2020). En el contexto de la creatividad y las FE, esto significa que las diferencias individuales en la estructura y el funcionamiento cerebral pueden llevar a una variedad de habilidades y estrategias para resolver problemas, innovar y regular el comportamiento. (Di Lieto et al., 2020; Renzulli y Reis, 2021).

La integración de una perspectiva neurodiversa en el ámbito educativo es particularmente relevante cuando se trabaja con estudiantes con NEAE. Estos estudiantes, que pueden incluir individuos con TDAH, dislexia, autismo o altas capacidades, requieren de enfoques pedagógicos adaptados que no solo atiendan sus desafíos, sino que también potencien sus fortalezas. Un enfoque inclusivo que reconozca la neurodiversidad puede ayudar a identificar y nutrir las capacidades creativas y ejecutivas de estos estudiantes, permitiendo un desarrollo más equilibrado y promoviendo el éxito tanto académico como social (Armstrong, 2012)

Por ejemplo, algunos estudios han mostrado que las personas con TDAH tienden a mostrar alta creatividad debido a su capacidad para pensar de manera no lineal, su impulso para buscar nuevas experiencias y su facilidad para generar ideas originales (White y Shah, 2011). Estas características, aunque pueden suponer un desafío en situaciones que requieren concentración y control de impulsos, pueden ser ventajosas en tareas que exigen creatividad y flexibilidad cognitiva.

Asimismo, las personas con dislexia pueden destacar en tareas que implican pensamiento visual-espacial, lo que las predispone a encontrar soluciones creativas a problemas que requieren una manipulación mental de imágenes y formas (Eide y Eide, 2023). Estos individuos suelen tener un enfoque diferente hacia el aprendizaje y la resolución de problemas, lo que a menudo les permite sobresalir en áreas creativas y artísticas, aunque puedan enfrentar dificultades en ámbitos como la lectura y la escritura.

Por otro lado, los individuos con altas capacidades suelen poseer una notable habilidad para integrar información compleja y generar ideas innovadoras. Según Renzulli (2012), estas

personas no solo muestran un alto rendimiento en pruebas de inteligencia, sino que también son capaces de combinar sus FE y creatividad de manera excepcional, lo que les permite sobresalir en la formulación de soluciones innovadoras y la elaboración de proyectos complejos.

El estudio de la creatividad y las FE desde una perspectiva neurodiversa ofrece una visión más rica y completa de estas habilidades cognitivas. Al reconocer que las diferencias neurológicas no son deficiencias sino variaciones naturales, se amplía la comprensión de cómo estas habilidades se desarrollan y se manifiestan de manera única en cada individuo. Así, en lugar de aplicar un enfoque uniforme que busque "normalizar" los comportamientos cognitivos, es más fructífero reconocer y celebrar las diversas formas de creatividad y control ejecutivo que diferentes cerebros pueden ofrecer (Armstrong, 2015).

2.7. LA PRESENTE TESIS DOCTORAL

Teniendo en cuenta el marco teórico anteriormente discutido, y a pesar de que la investigación sobre la creatividad y las funciones ejecutivas (FE) ha avanzado significativamente en los últimos años, persisten importantes lagunas en la literatura, especialmente en lo que respecta a su interrelación durante la adolescencia. La mayoría de los estudios se han centrado en analizar estos constructos de forma aislada, sin investigar adecuadamente cómo se influyen mutuamente. Esto es particularmente notable en muestras de niños y adolescentes, donde se ha observado una escasez de investigaciones que aborden simultáneamente la creatividad y las FE, a pesar de que ambas capacidades experimentan un desarrollo importante durante estas etapas. En el contexto de la adolescencia, los cambios neurobiológicos y cognitivos hacen que este grupo sea especialmente relevante para el estudio de la relación entre creatividad y FE, dado que estas habilidades son esenciales para la resolución de problemas, la toma de decisiones y la adaptación social y académica.

Además, la investigación existente ha tendido a centrarse en poblaciones neurotípicas, prestando poca atención a la variabilidad en los perfiles neurocognitivos, como aquellos presentes en adolescentes neurodivergentes. Estas limitaciones hacen que el conocimiento sobre cómo las FE y la creatividad se desarrollan e interactúan en diferentes grupos sea insuficiente, lo que deja sin explorar preguntas clave sobre la relación entre estos procesos en contextos de neurodiversidad.

Otra laguna en la investigación se refiere a las herramientas metodológicas utilizadas para evaluar la creatividad y las FE. La mayoría de los estudios se han basado en pruebas

tradicionales de lápiz y papel, que no siempre capturan adecuadamente la complejidad de estos procesos cognitivos. Este estudio empleará herramientas innovadoras, como la RV, para ofrecer una evaluación más dinámica y ecológicamente válida de las FE, lo que puede generar resultados más precisos y aplicables en contextos reales. Además, al analizar múltiples variables como la edad, el género, la inteligencia y el perfil neurocognitivo, se espera identificar patrones más específicos en la interacción entre creatividad y FE, proporcionando una visión más matizada y representativa del desarrollo cognitivo en la adolescencia.

Este estudio tiene una relevancia especial en el contexto psicoeducativo actual, donde hay un creciente reconocimiento de la importancia de las habilidades creativas y ejecutivas para el éxito académico y la adaptación social. Al abordar la diversidad de estilos de aprendizaje y capacidades neurocognitivas, el estudio proporciona un marco para el desarrollo de intervenciones pedagógicas personalizadas que fomenten un entorno de aprendizaje inclusivo y equitativo. Los insights obtenidos no solo enriquecerán el campo de la investigación sobre desarrollo cognitivo y creativo, sino que también ofrecerán aplicaciones prácticas para docentes psicólogos y otros profesionales dedicados al desarrollo infanto-juvenil.

Este enfoque permitirá mejorar la comprensión de cómo los adolescentes pueden ser apoyados en su desarrollo cognitivo y creativo, y ayudará a diseñar programas educativos que maximicen su potencial, independientemente de su perfil neurocognitivo. Además, los resultados obtenidos podrán servir como base para futuras investigaciones en el ámbito de la neuroeducación y la psicología del desarrollo, ampliando el conocimiento sobre cómo las capacidades cognitivas y creativas pueden ser fomentadas de manera conjunta.

Objetivos y Fases de Investigación de la Tesis Doctoral

El presente estudio tiene como objetivo general investigar comprehensivamente la interrelación entre las FE y la creatividad en adolescentes, tanto en poblaciones neurotípicas como neurodivergentes. Para abordar este objetivo general, el estudio se divide en tres fases metodológicas que permiten un enfoque exhaustivo y multidimensional de la investigación. Estas fases se explican por el proceso de investigación llevado a cabo y en cada una se concretan preguntas de investigación, objetivos específicos y estudios derivados de ello (Figura 1).

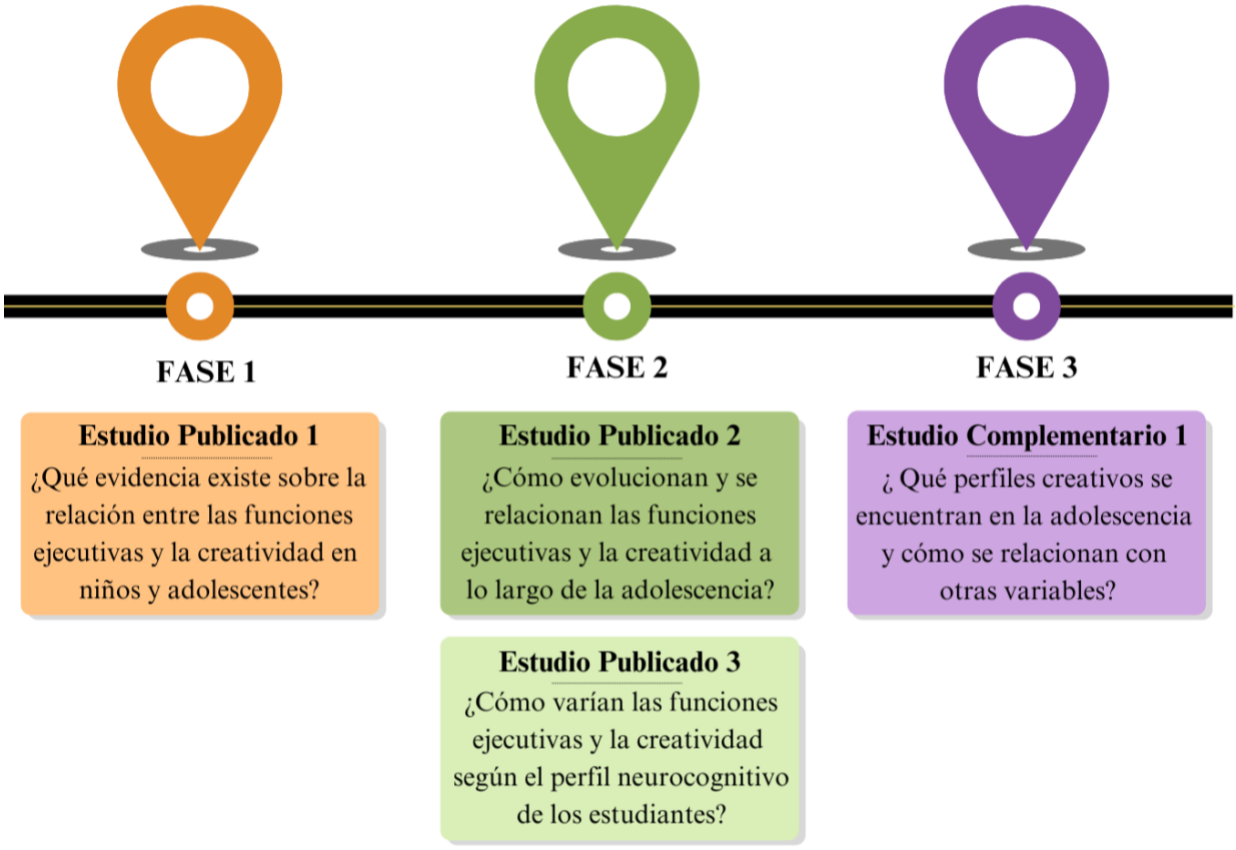

Figura 1. Fases de la investigación. *Elaboración propia*

Primera fase: Revisión sistemática y búsqueda inicial de la literatura

El primer paso consiste en una revisión sistemática de la literatura científica existente para identificar las investigaciones previas sobre la relación entre las FE y la creatividad en adolescentes. Pretende dar respuesta a la siguiente pregunta de investigación:

1. ¿Qué evidencia existe sobre la relación entre las FE y la creatividad en niños y adolescentes?

Esta pregunta se concreta en el objetivo del mismo estudio:

- **Objetivo 1:** Analizar la relación entre las FE y la creatividad en niños y adolescentes. A partir de esta revisión inicial, se busca mapear las principales lagunas en la literatura y fundamentar los siguientes estudios. Estudio Publicado 1: *"Relationship between Executive Functions and Creativity in Children and Adolescents: A Systematic Review".*

Segunda fase: Estudios empíricos preliminares sobre el desarrollo de las FE y la creatividad

La segunda fase se centra en la realización de dos estudios empíricos preliminares. El primero examina cómo se desarrollan evolutivamente las FE y la creatividad a lo largo de la adolescencia, mientras que el segundo analiza las diferencias entre estudiantes neurotípicos y neurodivergentes (p. ej., con TDAH, Dislexia) en relación con estas variables. Esta fase también incluye la publicación de dos artículos basados en lo anteriormente mencionado y que pretenden dar respuesta a las siguientes preguntas de investigación:

2. ¿Cómo evolucionan y se relacionan las FE y la creatividad a lo largo de la adolescencia?
3. ¿Cómo varían estas variables según el perfil neurocognitivo de los estudiantes?

Esta pregunta se concreta en los objetivos propios de los estudios:

- **Objetivo 2:** Examinar el desarrollo evolutivo de la creatividad y las FE a lo largo de la adolescencia, analizando cambios y relaciones a lo largo de esta etapa de transición. Este estudio explora cómo las FE y la creatividad se modifican con el tiempo en función de la edad y otros factores contextuales. Estudio Publicado 2: *" Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity".*
- **Objetivo 3:** Comparar la creatividad y las FE en diferentes perfiles neurocognitivos: adolescentes neurotípicos y neurodivergentes. El análisis de las diferencias entre estos grupos permitirá identificar cómo varían las trayectorias de desarrollo cognitivo y creativo, y aportará información valiosa para el diseño de intervenciones inclusivas. Estudio Publicado 3: *"Neurodivergent Students. A Continuum of Skills with an Emphasis on Creativity and Executive Functions"***.**

Tercera fase: Estudios avanzados a través de análisis de perfiles latentes

La última fase del estudio incluye un análisis más detallado de las interrelaciones entre creatividad y FE mediante un estudio complementario. Se centra en el análisis de perfiles latentes, con el objetivo de identificar distintos perfiles creativos en adolescentes, considerando factores como la neurodiversidad, el género y la inteligencia. En esta fase se plantea como complementario por estar en proceso de publicación y responde a las siguiente pregunta de investigación:

4. ¿ Qué perfiles creativos se encuentran en la adolescencia y cómo se relacionan con otras variables?

Esta pregunta se especifica en el objetivo específico del estudio:

- **Objetivo 4:** Identificar la existencia de perfiles creativos en adolescentes a través de un análisis de perfiles latentes, analizando factores como la neurodiversidad, el género, la inteligencia y la edad y explorando las implicaciones de estos perfiles en su desarrollo cognitivo. Este objetivo permitirá identificar grupos específicos que puedan beneficiarse de intervenciones educativas personalizadas. Estudio Complementario 1.

En conclusión, la revisión teórica presentada ha permitido establecer una comprensión sólida sobre la interrelación entre las FE y la creatividad, destacando la relevancia de ambas en el desarrollo cognitivo y académico durante la adolescencia. A partir de esta base teórica, en el siguiente capítulo se detallará el diseño de la investigación, en el que se explican los métodos utilizados para examinar empíricamente estas relaciones, incluyendo los instrumentos, el procedimiento y los enfoques analíticos empleados para responder a las preguntas planteadas en este estudio.

03

DISEÑO DE LA INVESTIGACIÓN

3.2. MÉTODO

En este apartado se expone el método empleado en los diferencias estudios que forman esta Tesis Doctoral, de acuerdo con las fases y objetivos planteados.

3.2.1. Revisión sistemática

Las revisiones sistemáticas son herramientas metodológicas ampliamente reconocidas por su capacidad para sintetizar de manera rigurosa y objetiva la evidencia científica existente (Kuckertz y Block, 2021). Este enfoque permite integrar grandes cantidades de información dispersa en la literatura y, mediante el análisis estadístico y cualitativo, derivar conclusiones robustas y basadas en datos sólidos. En el marco de esta Tesis Doctoral, el uso de una revisión sistemática ha sido clave para consolidar el conocimiento actual sobre la relación entre la creatividad y las FE. En este caso, se han seguido las directrices PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), que proporcionan una guía estandarizada para asegurar la transparencia, consistencia y reproducibilidad en la selección y análisis de estudios (Moher et al., 2014). PRISMA se ha establecido como un marco de referencia en la investigación empírica, especialmente por su capacidad para reducir el sesgo de selección y aumentar la fiabilidad de los resultados obtenidos.

Para la revisión sistemática (Fase 1 – Estudio publicado 1) se ha seguido el siguiente proceso de revisión:

1. **Formulación de la pregunta de investigación y criterios de inclusión/exclusión.** La revisión sistemática se diseñó en torno a preguntas de investigación claramente formuladas, basadas en los objetivos de la Tesis Doctoral. Se establecieron criterios de inclusión para asegurar la relevancia de los estudios seleccionados. Por ejemplo, se incluyeron estudios que: (1) investigaran la relación entre las FE y la creatividad en adolescentes; (2) utilizaran herramientas de medición validadas tanto para FE como para creatividad; (3) incluyeran al menos una medida de cada variable (FE y creatividad), entre otros.

   Los criterios de exclusión se definieron para eliminar estudios de baja calidad metodológica, aquellos con muestras no comparables, o que no reportaran suficientes datos cuantitativos.

2. **Búsqueda exhaustiva de estudios**. La búsqueda bibliográfica se realizó en varias bases de datos académicas relevantes (por ejemplo, Scopus o Web of Science), utilizando palabras clave específicas relacionadas con "funciones ejecutivas", "creatividad",

"pensamiento divergente" o “control cognitivo”. También se utilizaron operadores booleanos para refinar la búsqueda y asegurar la inclusión de estudios pertinentes.

Además, se realizaron búsquedas manuales en revistas especializadas y revisiones de citas de artículos clave para asegurar que no se excluyera ningún estudio relevante.

3. **Proceso de selección y cribado de estudios**. Los estudios recuperados se sometieron a un proceso de cribado en varias fases. En primer lugar, se eliminó cualquier duplicado y luego se realizó un cribado inicial basado en los títulos y resúmenes. Aquellos estudios que cumplían con los criterios de inclusión fueron seleccionados para una revisión completa del texto. Dos investigadores independientes llevaron a cabo esta revisión para minimizar el sesgo y aumentar la fiabilidad del proceso. Los desacuerdos se resolvieron mediante discusión y consenso.
4. **Extracción y codificación de datos**. Una vez seleccionados los estudios finales, se procedió a la extracción de datos clave, incluyendo las características de los participantes (origen, tamaño de la muestra, edad), las herramientas utilizadas para medir las FE y la creatividad, los resultados obtenidos y las conclusiones de los autores. Estos datos fueron codificados en una matriz estructurada para facilitar el análisis posterior, asegurando que toda la información relevante fuera organizada de manera sistemática y coherente.

El desarrollo de una revisión sistemática en esta Tesis Doctoral permite una comprensión profunda y matizada de la relación entre la creatividad y las FE, garantizando que las conclusiones se basen en una evaluación exhaustiva y rigurosa de la literatura científica. Esta metodología no solo fortalece la validez de los resultados obtenidos, sino que también proporciona una base sólida para futuras investigaciones y aplicaciones prácticas en contextos educativos y clínicos.

3.2.2. Estudios empíricos

3.2.2.1. Muestra

La muestra inicial de la investigación fue de 182 estudiantes (94 chicos y 88 chicas) de edades comprendidas entre los 12 y los 16 años (M = 13,21, DT = 1,19), con un CI medio de 101,44 (DT = 13,21). En la muestra se cuenta con un total de 23 participantes (12,68%) que tenían NEAE: 5 con altas capacidades, 7 con TDAH, 7 Dislexia, 3 con DI y 1 con Trastorno del Espectro del Autismo. Los participantes eran equivalentes en cuanto a edad y sexo y eran pertenecientes a dos centros educativos del norte de España.

En función del estudio realizado y sus criterios de inclusión, se consideraron diferentes muestras finales, lo que permitió ajustar la selección de participantes según los objetivos específicos de cada estudio. Los detalles sobre estos criterios de inclusión y las muestras finales derivadas de ellos se presentan en la Tabla 5, proporcionando una visión clara de cómo se estructuraron los grupos de estudio en cada uno de los trabajos de esta Tesis Doctoral.

Tabla 5.

Muestras finales por estudio

Estudio	**Criterios de inclusión**	**Muestra final**
Estudio Publicado 2	(1) estudiantes sin NEAE; (2) de 1º a 4º de educación secundaria; (3) que asisten regularmente al centro educativo.	159 estudiantes de secundaria (78 chicas y 81 chicos; M_{age} = 13,29; DT_{age} = 1,17 años). Cuatro grupos en función del curso escolar: 1º curso (n = 55); 2º curso (n = 58); 3º curso (n = 13); 4º curso (n = 33).
Estudio Publicado 3	(1) estudiantes que no presentan ningún otro trastorno comórbido; (2) de 1º a 4º de educación secundaria y que asisten regularmente; (3) demuestran suficientes capacidades de comprensión para realizar las tareas de creatividad y FE.	181 estudiantes de secundaria (93 chicos, 88 chicas M_{age}=13,33; DT_{age}=1,19;). Dos grupo en función del diagnóstico formal: alumnado neurotípico (N=159) y alumnado neurodivergente (N=22).
Estudio Complementario 1	(1) estar cursando entre 1º y 4º de secundaria; (2) asistir al colegio regularmente; y (3) haber completado todas las pruebas.	182 estudiantes de secundaria (94 chicos y 88; M = 13,34, DT = 1,19). Un total de 23 participantes tenían NEAE (5 altas capacidades, 7 con TDAH, 7 dislexia y 4 otras NEAE).

Elaboración propia

3.2.2.2. Variables e instrumentos

Pensamiento divergente.

PIC-J. Prueba de Imaginación Creativa para Jóvenes (Artola et al. 2008) es una prueba para evaluar la creatividad, medida como pensamiento divergente, en sujetos de entre 12 y 18 años. Consta de cuatro juegos: tres evalúan la creatividad verbal, mientras que el cuarto evalúa la creatividad gráfica. Para los estudios empíricos (Estudios Publicados 2 y 3 y Estudio Complementario 1) se utilizaron el juego 2 y el juego 4. El juego 2 consiste en una prueba de posibles usos de un objeto para evaluar la fluidez verbal, la flexibilidad verbal y la originalidad verbal. El juego 4 utiliza un test de imaginación gráfica inspirado en el Test de Torrance (TTCT; Torrance, 1998) para evaluar la creatividad figurativa basada en las dimensiones de originalidad y elaboración. Incluye las variables Título y Detalles gráficos. Los autores comprobaron las propiedades psicométricas y la fiabilidad de la prueba, obteniendo un alfa de Cronbach para el conjunto de la prueba de 0,85%.

Funciones ejecutivas.

Nesplora Funciones Ejecutivas – Icecream mide varios componentes de la FE y el aprendizaje en niños a partir de 8 años a través de una experiencia inmersiva con RV. La prueba consiste en la recreación durante 20-45 minutos de un entorno multitarea realista basado en la premisa *"es tu primer día de trabajo en una heladería"*. Hay que seguir varias reglas y cumplir objetivos para completar los retos planteados. La validez ecológica de este test permite medir la FE, maximizando el valor predictivo del rendimiento funcional real de la persona evaluada. *Nesplora Funciones Ejecutivas - Icecream* tiene una validez ecológica muy buena por ser un test adaptativo, pero, además, todas las variables principales del test muestran una fiabilidad a través de los coeficientes Omega de McDonald de entre .85 y .97 (Fernández et al., 2023). El test mide las FE de planificación, memoria de trabajo, velocidad de procesamiento y flexibilidad cognitiva.

Inteligencia.

En este estudio se ha utilizado la adaptación española del WISC-V (Wechsler, 2014). La consistencia interna de la adaptación española del WISC-V se ha examinado mediante el método de las dos mitades. La fiabilidad del CI (FSIQ) es de .95 (Amador & Forns, 2019). En este estudio se utilizan las 7 medidas principales utilizadas para obtener el cociente intelectual (CI) a escala completa. Para ello se utilizan: Semejanzas y Vocabulario para el índice Comprensión Verbal; Bloques para Visoespacial; Matrices y Balanzas para Razonamiento

Fluido; Dígitos para Memoria de Trabajo; y Claves para Velocidad de Procesamiento. Con estas medidas se obtuvieron el Índice de Comprensión Verbal (ICV) y el Índice de Razonamiento Fluido (IRF).

3.2.2.3. Procedimiento

El estudio se realizó de acuerdo con el Código Ético de la Asociación Médica Mundial (Declaración de Helsinki), que refleja los principios éticos para la investigación con seres humanos (Asociación Médica Mundial, 2013). El estudio fue aprobado por el Comité de Ética del Principado de Asturias (referencia: CEISH-UPV/EHU, BOPV 32) y todos los procedimientos se ajustaron a las leyes y directrices institucionales pertinentes. Se recogieron datos de niños, colegios y padres.

Las FE fueron evaluadas por un psicólogo especializado en el uso de la herramienta (*Nesplora Ice-Cream*) y se realizó en grupos de 5 alumnos debido a la naturaleza de la prueba. La evaluación de la creatividad y de la inteligencia fue realizada individualmente por cuatro especialistas en psicología de la Universidad de Oviedo que habían sido previamente formados en el uso de las pruebas. El alumnado fue organizado de forma natural por curso escolar y el muestreo fue por accesibilidad. Las pruebas se realizaron a lo largo de dos semanas en cada centro educativo, con un máximo de un día entre las dos pruebas para cada alumno. El orden de las pruebas fue aleatorio en la muestra, una parte del grupo hizo primero la prueba de inteligencia y creatividad y la otra parte del grupo hizo la prueba de FE y viceversa. La evaluación total de cada sujeto duró dos horas y media divididas en dos sesiones.

3.2.2.4. Análisis de datos

El análisis de los datos en esta Tesis Doctoral se ha llevado a cabo utilizando diferentes técnicas estadísticas apropiadas para cada uno de los estudios realizados. En total, se han desarrollado tres estudios con enfoques analíticos distintos, que han permitido examinar de manera exhaustiva la relación entre la creatividad, las FE y las diferencias neurodiversas en adolescentes.

Estudio publicado 2: Análisis de varianza y regresión jerárquica

En el primer estudio, se utilizaron análisis estadísticos descriptivos y paramétricos. Los datos fueron procesados mediante el software SPSS 27.0. En primer lugar, se calcularon los estadísticos descriptivos para las variables de interés y se verificó la normalidad de los datos a través de indicadores de curtosis y asimetría.

Posteriormente, se realizaron análisis de varianza (ANOVA) y análisis multivariado de varianza (MANOVA) para examinar la perspectiva evolutiva de las FE y la creatividad (pensamiento divergente). Las diferencias entre los grupos fueron evaluadas con el test de comparaciones múltiples de Scheffé, y se calcularon los tamaños del efecto usando el eta parcial al cuadrado (ηp^2), siguiendo los criterios de Cohen (1988). Un valor de $p \leq 0.05$ fue considerado como estadísticamente significativo.

Finalmente, se llevó a cabo un análisis de regresión jerárquica para predecir la influencia de las variables estudiadas sobre la inteligencia. Este modelo de regresión se estructuró en tres pasos: en el primer modelo se incluyeron las variables de edad y género, en el segundo modelo se añadieron las FE, y en el tercer modelo se añadieron las variables relacionadas con la creatividad.

Estudio publicado 3: Análisis multivariado con covariables

El segundo estudio también utilizó el software SPSS 27.0. Se calcularon los estadísticos descriptivos y se verificaron los indicadores de normalidad para las variables de creatividad y FE. A continuación, se realizó un análisis multivariado de covarianza (MANCOVA) para evaluar el efecto de la neurodiversidad, tomando como covariables la edad y el cociente intelectual (CI).

El test de comparaciones múltiples de Scheffé fue utilizado para identificar diferencias significativas entre los grupos neurotípicos y neurodivergentes en habilidades creativas y de funciones ejecutivas específicas (fluidez verbal, flexibilidad verbal, originalidad verbal, originalidad figurativa, memoria de trabajo, etc.). Los tamaños del efecto fueron calculados de acuerdo a los criterios de Cohen (1988), donde un valor $d < 0.20$ indica un efecto mínimo, entre 0.20 y 0.50 un efecto pequeño, entre 0.50 y 0.80 un efecto moderado, y > 0.80 un efecto grande. Los resultados se consideraron estadísticamente significativos con un valor de $p \leq 0.05$.

Estudio complementario 1: Análisis de perfiles latentes y evaluación de diferencias entre perfiles

El tercer estudio empleó un enfoque más avanzado para el análisis de datos, utilizando análisis de perfiles latentes (LPA) con el software Mplus v.6.11. Primero, se examinaron las propiedades estadísticas de las variables y se trataron los valores perdidos mediante la imputación múltiple. Para identificar perfiles creativos, se utilizaron siete medidas de creatividad, tanto verbales como figurativas.

El ajuste de los modelos se basó en los criterios de Lo-Mendell-Rubin Adjusted Likelihood Ratio Test (LMRT), el Akaike Information Criterion (AIC), el Bayesian Information Criterion (BIC) y el sample size-adjusted BIC (SSA-BIC). Un menor valor en estos indicadores sugirió un modelo más parsimonioso, mientras que el valor p del LMRT indicó si la solución con más clases era más adecuada. Se utilizó el comando automático DE3STEP de Mplus para estimar diferencias entre los perfiles creativos en relación con cinco variables externas (incluyendo el CI y la memoria de trabajo).

Los tamaños del efecto también se calcularon utilizando los criterios de Cohen (1988), y el método de estimación utilizado fue maximum likelihood estimation con error estándar robusto (MLR), lo cual permitió una mayor precisión en los resultados.

A través de estos tres enfoques analíticos—ANOVA y regresión jerárquica en el primer estudio, MANCOVA en el segundo, y análisis de clases latentes en el tercero—se han proporcionado diferentes perspectivas sobre la relación entre las FE, la creatividad y la neurodiversidad en adolescentes. Este análisis exhaustivo permite no solo validar las hipótesis planteadas, sino también establecer conclusiones robustas que podrán contribuir a la creación de intervenciones pedagógicas más inclusivas y personalizadas.

04

ESTUDIOS DE LA TESIS

4.1. ESTUDIOS PUBLICADOS

A continuación, se presentan los trabajos publicados que conforman esta Tesis Doctoral y la información relativa al Factor de Impacto de las revistas en las que han sido publicados. Todos los estudios han sido publicados en revistas incluidas en *JCR Social Science Edition* y por ello se aporta la información de la *Web of Sciences (WOS)*.

Estudios publicados

Estudio Publicado 1: Pasarín-Lavín, T., Abín, A., García, T. & Rodríguez, C. (2023). Relationship between Executive Functions and Creativity in Children and Adolescents: A Systematic Review. *Children*, *10*, 1002. https://doi.org/10.3390/children10061002

Factor de impacto: JCR 2023 2.0 (Cuartil 2)

Posición 68/186, categoría "Pediatrics"

Estudio Publicado 2: Pasarín-Lavín, T., García, T., Rodríguez, C., Núñez, J.C., y Areces, D. (2024). Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity. *Thinking Skills and Creativity*, *51*, 101466. https://doi.org/10.1016/j.tsc.2024.101466

Factor de impacto: JCR 2023 3.5 (Cuartil 1)

Posición 53/756, categoría "Educacion & Educational research"

Estudio Publicado 3: Pasarín-Lavín, T., García, T., Abín, A., & Rodríguez, C. Neurodivergent Students. A Continuum of Skills with an Emphasis on Creativity and Executive Functions. *Applied Neuropsychology: Child*. https://doi.org/10.1080/21622965.2024.2406914

Factor de impacto: JCR 2023 1.4 (Cuartil 3)

Posición 66/92, categoría "Psychology"

ESTUDIO PUBLICADO 1:

Relationship between Executive Functions and Creativity in Children and Adolescents: A Systematic Review

Autores

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Palabras clave

Creativity, executive functions, intelligence, working memory, inhibition, switching

Factor de impacto

JCR 2023 2.0 (Cuartil 2); posición 68/186, categoría "Pediatrics"

children

MDPI

Review

Relationship between Executive Functions and Creativity in Children and Adolescents: A Systematic Review

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Abstract: (1) Background: Executive functions and creativity could play an important role in children's education. To date, research on the relationship between these constructs has focused on adults. The objective of this systematic review was to analyze the relationship between executive functions (EFs) and creativity in children to provide teachers with tools to improve students' abilities. (2) Methods: A total of 12 studies were identified using WOS, SCOPUS and PsycINFO, which matched the following criteria: (i) empirical studies with measures of executive functions and creativity; (ii) a sample of children or adolescents (3 to 18 years old); and (iii) in the previous decade (2012–2021). (3) Results: The results indicated a clear relationship between flexibility and creativity. Flexibility is positively correlated and inhibition is negatively correlated with creativity. There is no clear evidence that the remaining EFs, such as working memory, correlate with creativity. There was insufficient evidence on the relationship between intelligence, executive functions and creativity in a sample of children for the results to be generalized. (4) Conclusion: Future studies should consider the variability of standardized tests that measure these two constructs in order to be able to compare measurements and obtain generalizable results.

Keywords: creativity; executive functions; intelligence; working memory; inhibition; switching

Abstract

(1) Background: Executive functions and creativity could play an important role in children's education. To date, research on the relationship between these constructs has focused on adults. The objective of this systematic review was to analyze the relationship between executive functions (EFs) and creativity in children to provide teachers with tools to improve students' abilities. (2) Methods: A total of 12 studies were identified using WOS, SCOPUS and PsycINFO, which matched the following criteria: (i) empirical studies with measures of executive functions and creativity; (ii) a sample of children or adolescents (3 to 18 years old); and (iii) in the previous decade (2012–2021). (3) Results: The results indicated a clear relationship between flexibility and creativity. Flexibility is positively correlated and inhibition is negatively correlated with creativity. There is no clear evidence that the remaining EFs, such as working memory, correlate with creativity. There was insufficient evidence on the relationship between intelligence, executive functions and creativity in a sample of children for the results to be generalized. (4) Conclusion: Future studies should consider the variability of standardized tests that measure these two constructs in order to be able to compare measurements and obtain generalizable results.

Keywords: creativity; executive functions; intelligence; working memory; inhibition; switching

1. Introduction

The relationship between executive functions (EFs) and creativity has been thoroughly studied in samples of adults [1–4]. Many of our higher cognitive processes are put into action for us to be creative: working memory, flexibility, planning and inhibition, among others. This is why it is essential to understand the importance of EFs in creativity—taking into account the mediating value of intelligence, since it has been widely investigated in relation to creativity [5,6]. Over recent years, creativity and EFs have been highly valued and sought-after constructs in society [7], and scientific evidence shows that EFs play an important role in adult creativity [8,9]. The present study aims to analyze this relationship in a sample of children and adolescents.

1.1. Executive Functions (EFs)

EFs refer to higher mental processes allowing flexible and complex functions that direct behavior towards a goal [10]. In general, inhibition, working memory and shifting are considered the main executive processes [11] that other processes, such as planning, problem solving, etc., depend on [12].

It is well known that EFs present a common but independent variance factor, meaning that there is no perfect correlation between them [11]. This is why the three processes of working memory, inhibition and shifting should be included when evaluating EFs. Inhibition is the ability to inhibit or control automatic responses; working memory is the ability for temporary storage and processing of information; and shifting is the ability to unconsciously shift attention from one task to another [11,13].

Proper development of these EFs makes daily life easier. Additionally, a deficit in some of these functions is key to the diagnosis of some educational needs, such as ADHD [14], so much so that authors such as Filippetti and Richaud [15] claim that the development of EFs improves academic performance. This observation makes it important to know how they relate to other constructs, such as creativity and intelligence.

1.2. Creativity

Like with EFs, several authors [16–18] related creativity to an improvement in academic performance. In fact, creativity is one of the most widely-demanded skills in modern society in order to pursue a professional career [19].

The theoretical models that explain creativity begin with Guilford [17], who explained that creativity is made up of five components: (1) sensitivity, as the ability to quickly detect problems in order to solve them; (2) fluency, as the ability to produce a large number of ideas, words or associations; (3) flexibility, as the ability to switch from one idea to another, from one context to another, and to give varied responses; (4) elaboration, as the ability to perceive deficiencies, generate ideas and refine them to obtain new and improved versions; and (5) originality, as the ability to produce unusual ideas or responses. From Guilford, we move on to Csikszentmihalyi [20], who noted that creativity occurs in the interaction between a person's thoughts and a sociocultural context considering three elements: (1) the domain, which consists of a set of rules in the culture of a society; (2) the field, which includes the individuals who give access to the field, for example, teachers; and (3) the person, who uses the rules of the field, interacts with the field and produces creativity.

Hence, creativity is a multifaceted construct which can be studied from various perspectives in the field of education. The two main forms of creativity are as follows: (1) divergent and convergent or (2) verbal and figural, although it can also be studied through its components, including fluency, flexibility, originality and elaboration [21]. However, we still need to know what makes certain people more creative than others. Alternatively, authors such as Rhodes [22] and Treffinger et al. [23] defined creativity with four Ps: person, product, process and pressure-context.

1.3. Executive Functions (EFs), Creativity and Intelligence

EFs are mainly important in generating new ideas for which flexibility is key [24]. This means that EFs are seen as fundamental elements for the creative process, and, hence, must be studied jointly [25].

This relationship has been carefully analyzed in samples of adults by many authors. Some found statistically significant results in this relationship, especially with regard to EFs, such as inhibition, working memory and flexibility [26–28].

Other authors found positive relationships in some of these EFs, for example, between working memory and creativity measured with various tasks [1,29]. It has been suggested that creativity needs information retrieved from memory to build new ideas [29]. The literatura also indicates evidence of a relationship between inhibition and creativity, explaining that a lack of cognitive control benefits creativity, specifically with fluency and flexibility but not with originality [30,31]. Moreover, creativity seems to be related to shifting because it requires flexibility of thought to produce new and different ideas [3,26].

Many studies have demonstrated relationships between EFs and creativity, although the vast majority agree that the relationship depends on the measures used for each variable.
Finally, the intelligence–executive functions and intelligence–creativity binomial have been studied in recent years. The first seems to show more support, since authors such as Frith et al., Karwowski et al., and Silvia [32–34] found that executive tests correlate significantly with the results in intelligence tests, which leads them to affirm that the administered executive tests constitute an excellent measure of general intelligence. The intelligence–creativity binomial is more controversial, and no agreement has been reached on whether this relationship exists, but the latest studies in adults [35,36] agree that the relationship between these two constructs is significant.

Taking this into account, in order to analyze the relationship between creativity and executive functions, it is important not to leave aside the intelligence variable. Some of these studies have also assessed intelligence as a mediating variable in this relationship [30,37]. Authors such as Benedek et al. [1] showed that working memory was found to explain a notable part of the shared variance between intelligence and creativity. Benedek et al. [30] examined whether the relationship between EFs and creativity was mediated by intelligence. They found that inhibition primarily promoted the fluency of ideas, whereas intelligence specifically promoted the originality of ideas. Other authors have explained that working memory is a predictor of individual differences in intelligence [38].

1.4. The Current Review

In summary, it could be said that these factors are essential for school and life. Executive functions and creativity prepare children and adolescents to adapt to unforeseen changes and challenges that may occur in the future of our society [39,40]. However, these constructs have been extensively studied separately and the studies that relate one to the other have focused on adults. This may be because it is easier to evaluate these skills in adults. As indicated above, several studies have shown a relationship between creativity and EFs in adults, and it is important to confirm whether the same occurs in younger people. The relationship with intelligence is currently not clear, however, nor is it clear whether it is a mediator in the relationship between EFs and creativity.

Therefore, we set out to review the empirical work investigating these relationships in samples of children and adolescents (from 3 to 18 years old). The study was limited to research published in the last 10 years (2012–2021). Importantly, the current review is expected to offer contributions to education, literature and future research. Additionally, the results are expected to help teachers and schools to work on more EF-focused strategies to develop creativity and ability in students.

More specifically, the following research questions guided this systematic review:

RQ1. What is the relationship between creativity and EFs in children?

RQ2. Is intelligence a mediating variable in this relationship?

2. Materials and Methods

Systematic reviews are solid syntheses of evidence that aim to bring together a complete description of the knowledge in a particular field of research in a single document [39,40]. To ensure the quality and rigor of a systematic review, the documentation supporting the review process should be complete and include the following considerations: formulation of questions, the definition of inclusion and exclusion criteria, the definition of the search formulation, etc. [41]. The PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) provide a checklist for reviewers on how to report a systematic review and allows the rigorous analysis of all the studies found [42].

2.1. Search Strategy

The literature search used multidisciplinary databases (WOS and SCOPUS) and one specific database (PsycINFO) in March 2022. The main objective was to analyze the relationship between creativity and EFs, and the keywords used for the search were as follows: (“Creativity” OR “creative thinking” OR “creative ability” OR “divergent thinking” OR “originality”) AND (“executive function*” OR “cognitive control” OR “executive control”). Moreover, a multi-method approach was used to improve the review by including

two points of view: a quantitative view using methodological search tools through search equations in databases and a qualitative filtering of the references of the articles read that were not included in the previous databases.

2.2. Selection Criteria

The inclusion and exclusion criteria were defined to extend our knowledge about the relationship between EFs and creativity. To be included in this systematic review, articles had to meet the following criteria: (i) written in English or Spanish; (ii) included a sample of children or adolescents attending school (age range from 3 to 18 years old); (iii) empirical studies, with at least one measure of EFs and one of creativity; (iv) full-text available; (v) sufficient descriptive statistics (age, origin, gender, N); (vi) published in the previous ten years (2012–2021); and (vii) provides statistical and correlational data between EFs (flexibility, working memory, inhibition) and creativity.

In contrast, articles were excluded when they met the following criteria: (i) studies focusing on fMRI or neuroimaging; (ii) intervention studies focusing on pretest; (iii) studies with insufficient information describing sample (N, gender, age, origin); (iv) clinical studies of individuals with pathologies; (v) studies not indexed in JCR or SJR journals; and (vi) theoretical research, books, handbooks and all types of gray literature.

2.3. Data Extraction

Endnote was used as a data manager in the article selection process. The first selection phase was based on ordering and identifying the articles by title. In instances where the title did not clearly indicate the object of the study, we continued to the next phase, which consisted of reading the abstract. If there were still doubts about compliance with the inclusion criteria, we moved to the full reading in the eligibility phase. In the first selection phase, the authors of the present review analyzed the inclusion and exclusion criteria, and in the eligibility phase, all full texts were independently analyzed by two reviewers to ensure rigor and to ensure that inclusion criteria were met.

The following information was collected from each article: type of study, year, journal, author, title, country of the sample, aims, variables, sample and age range, study design, evaluation instruments used and summary of the results.

2.4. Study Selection

A total of 1357 studies were found in the database searched (561 from WOS, 466 from Scopus, and 330 from PsycINFO). Duplicates (n = 579) were removed, and 680 papers were excluded by title (n = 604) or abstract (n = 76). In total, 98 articles were selected for eligibility assessment but only 80 had the full text available for analysis to produce the final sample.

Ultimately, a total of 11 studies met the inclusion criteria, and the references in those papers were analyzed to find additional studies. This produced 52 potentially relevant papers. Additionally, 32 duplicates and 15 papers that were already in the previous review (3 that met the inclusion criteria and 12 that were excluded previously) were excluded. Subsequently, 5 studies were selected by abstract to analyze by full-text, only 1 of which met selection criteria. Finally, a total of 12 articles (11 from databases and 1 from reference selection) were selected, as shown in the following flowchart (Figure 1) that complies with the PRISMA Declaration [43].

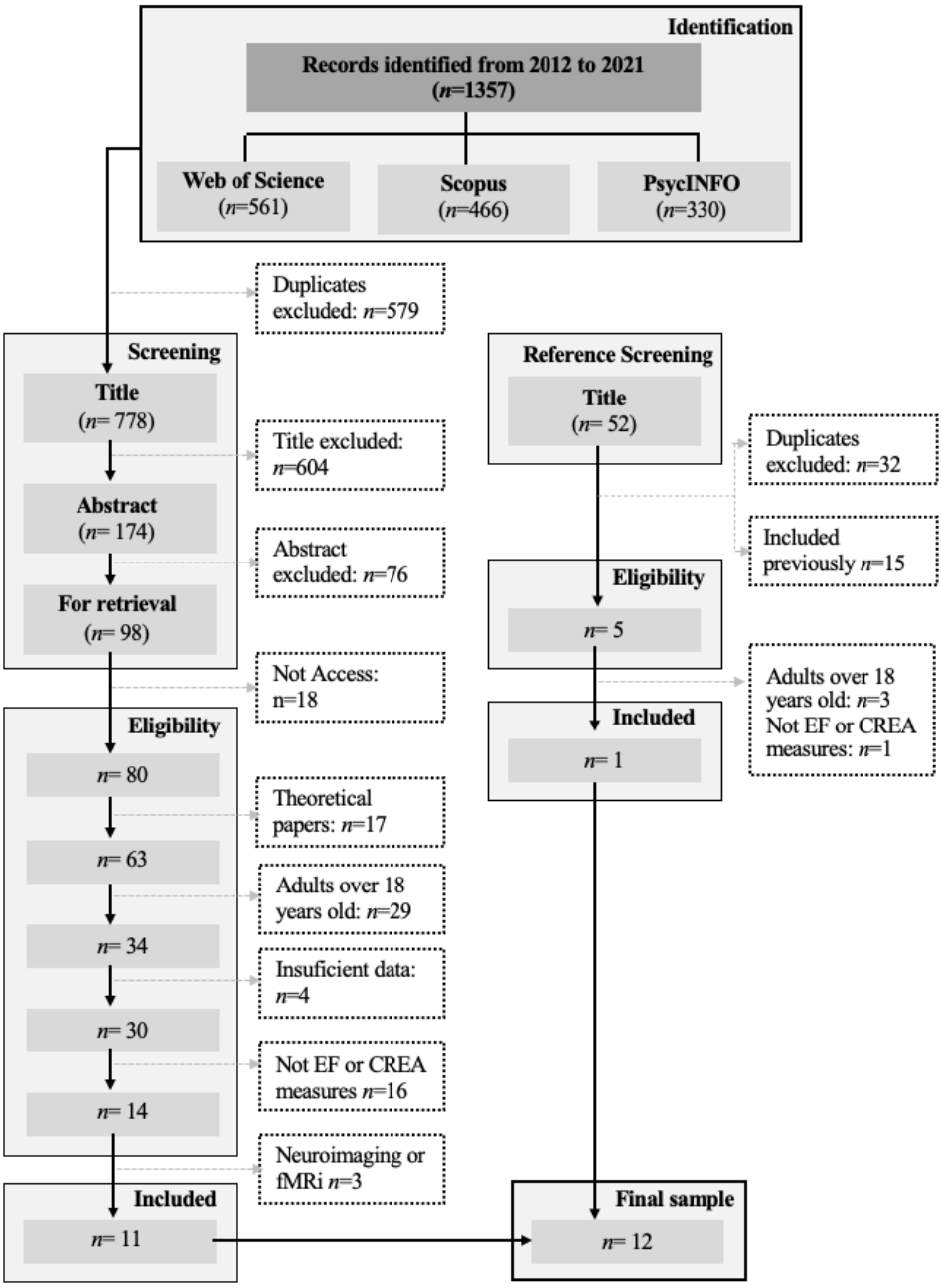

Figure 1. Flowchart based on PRISMA

First author (year)	Sample			Measures	Outcomes
	Location	**Size/Design**	**Age range**		
Filippetti et al. (2020)	Argentina	**Study 1:** 112 children (M=91.75; SD=10.56) **Study 2:** 177 children (M=9.94; SD=1.24) **Descriptive design and Structural equation model (SEM)**	**Study 1:** 8-12 years **Study 2**: 8-13 years	**Study 1:** **Intelligence:** K-BIT; **Flexibility:** (1) Wisconsin Card Sorting Test; (2) Trail Making Test; (3) Five Point Test; (4) Semantic Verbal Fluency; (5) Phonological Verbal Fluency; **Working Memory:** Digits, Letters and numbers (WISC-IV). **Inhibition:** (1) Stroop color and Word Test; (2) NEPSY, Knock and Tap; (3) D2, Attention test (Spanish adaptation) **Reading and writing:** (1) Reading comprehension test (ENI); (2) PROESC writing test **Study 2:** **Creativity:** (1) Figural Torrance Test (TTCT); (2) CREA; **Flexibility:** Same of numbers (1) and (3) in study 1; **Working memory:** Same of study 1; **Inhibition**: Same of number (1) in study 1**;** **Intelligence**: Same of study 1	**Study 1:** Working Memory and Inhibition together contribute and support flexibility. This contribution depends on the tasks used and Inhibition contribution may depend on age. **Study 2:** There are consistent relationship between flexibility and creativity. Being creative requires a flexible thinking but depends on the tasks used and the type of flexibility measured (spontaneous or reactive).
Bai et al. (2021)	Netherlands	102 children (M= 5.93; SD= 0.27) **Descriptive design and Multilevel regressions (longitudinal)**	5.45-6.53 years	**Divergent Thinking:** (1) Alternative Uses Task; **Inhibition**: (1) Programmed in E-Prime Go/NoGO task; (2) Animal Stroop task; **Shifting**: (1) Dimensional Change Car Sort (DCCS); (2) Animal shifting task; **Memory:** (1) Word Recall Backwards; **Selective Attention:** (1)	Executive functions such as attention and specific processes influence and are related to the creation of original ideas. The influence of inhibition and working memory cannot be confirmed, not predict/moderate originality.

				Visual search task programmed in E-Prime (ad-hoc)	
De Chantal et al. (2017)	Canada	**Study 1:** 32 children (M=53.3 months) **Study 2:** 32 children (M = 47.06 months) **Correlational design and hierarchical regression**	**Study 1:** 41-64 months **Study 2:** 32–61 months	**Creativity:** (1) Generation task. Three different problems (ad-hoc); **Inhibition:** (1) DCCS task; **Reasoning**: (1) Logical reasoning task with a sets of problems (ad-hoc)	Inhibition plays an important role in children's reasoning. The idea generation task is very similar to the creativity tests, so it can be said that creativity and some executive functions share mental processes.
Krumm et al. (2020)	Argentina	200 children (M= 10.01; SD= 1.24) **Correlational design**	8-13 years	**Creativity:** (1) Figural Torrance Test (TTCT) (2) CREA; **Intelligence:** (1) K-BIT; **Working Memory:** (1) Digits, letters and numbers of WISC-IV; **Inhibiton:** (1) Stroop color-word test; **Shifting:** (1) Wisconsin Card Sorting Test Computer version; **Verbal Fluency:** (1) Semantic and phonological verbal test (fruits and animals); **Nonverbal Fluency (shifting):** (1) Five-Point Test; **Planning:** (1) Porteus Maze Test	There are significant differences in the EF: (1) Working Memory would be involved in the search for creative ideas. (2) Inhibition (measured with Stroop) is positively related to creativity because it eliminates the interference of dominant responses. (3) Cognitive Flexibility is associated with fluency and creative flexibility and not with originality.
Krumm et al. (2018)	Argentina	209 children aged (M=9.96; SD=1.23)	8-13 years	**Creativity:** (1) Figural Torrance Test (TTCT) (2) CREA; **Intelligence:** (1) K-BIT; **Working Memory:** (1) Digits,	Positive correlation between creativity, flexibility, inhibition and intelligence. All executive

		Correlational and SEM		letters and numbers of WISC IV; **Inhibiton:** (1) Stroop color-word test; **Shifting:** (1) Wisconsin Card Sorting Test Computer version; **Verbal Fluency:** (1) Semantic and phonological verbal test (fruits and animals); **Nonverbal Fluency (shifting):** (1) Five-Point Test	functions correlate with creativity, but only inhibition and flexibility predicted creativity with intelligence as the mediating variable.
Sánchez-Macías et al. (2021)	Spain	96 students (M=14,5; SD= 0.85) **Correlational design**	14-17 years	**Creativity:** (1) Torrance Test of Creative Thinking (TTCT); **Working Memory:** (1) WISC-IV (Spanish adaptation; **Planning:** Hanoi Tower; **Inhibition:** (1) Stroop Test; (2) Go/noGO; **Shifting:** (1) Wisconsin Card Sorting Test; **Decision making:** Iowa Gambling task.	Positive correlation between creativity and flexibility and negative correlation between creativity and verbal inhibition. The correlations between creativity and the rest of the executive functions are not significant.
Stolte et al. (2020)	Netherlands	278 children (M= 9.71; SD= 0.93) **Correlational design and SEM**	8-13 years	**Inhibition:** (1) Fish Game; **Shifting:** (1) Second block of the Fish Game; **Working Memory:** (1) Monkey Game to verbal updating; (2) Lion Game to visuo-spatial updating; **Mathematical Creativity (MC):** (1) MC Test Dutch translation; (2) Cito test; **General creativity:** (1) Test for Creativity Thinking Drawing production.	Positive correlation between creativity (general and specific) and working memory, but the role of inhibition and flexibility in creativity and mathematics cannot be generalized.
Stolte et al. (2019)	Netherlands	**Fluency:** 80 participants (M=9.95; SD=0.84) **Flexibility:** 82 participants (M=9.93; SD=0.82) **Originality:** 81 participants	8-12 years	**Inhibition:** (1) Fish game; **Mathematical ability:** (1) Cito test; **Mathematical Creativity (MC):** (1) MC Test Dutch translation.	Results showed that mathematical creativity significantly correlated with components such as flexibility, fluency and originality. In the same way, that flexibility and originality significantly correlates with inhibition and this in turn produces a stronger relationship between mathematical

		(M=9.96; SD=0.82) **Correlational design and hierarchical multiple regression**			ability and mathematical creativity of students.
Vaisarova et al. (2021)	USA	**<u>Experiment 1.</u>** 103 children (53 4-year-old (M=48.5 months) / 50 6-year-old (M= 72.4 months) **<u>Experiment 2.</u>** To avoid age bias in Experiment 1, 78 5-year-old children with typical development from a university database were recruited (*M* = 66.7 months) **Comparative and Experimental design**	4-6 years	**<u>Experiment 1.</u>** **Executive Functions:** (1) Minnesota EF scale; **Effortful Control:** (1) Children's Behavior Questionnaire (parents completed); **Creativity:** (1) Adaptation of Montweiler and Taylor's; **Divergent Thinking:** (1) AUT for preschoolers (Adaptation of Wallach and Kogan's); **Intelligence:** (1) Stanford-Binet Nonverbal Fluid Reasoning and Verbal Knowledge routing subtest **<u>Experiment 2.</u>** **Excutive Functions:** (1) Same of experiment 1; (2) Flexible Item Selection Task (FIST) (3) Backward Digit Span; **Effortful Control:** (1) Same of experiment 1; **Intelligence:** Same of experiment 1; **Conformity:** (1) Adaptation of the Asch Social conformity paradigm; **Divergent Thinking:** Same of experiment 1	Both studies showed negative relationships between EF and creativity. This suggests that cognitive skills do not enhance divergent and creative thinking and may take a backseat.

Van Dijk et al. (2020)	Netherlands	70 (M=11.07; SD= 0.69; 36 low stimulus; 34 high stimulus) **Correlational design**	9-12 years	**Creativity:** (1) Alternative Uses Task (visual) Computer task; (2) Semantic categories of the Torrance Test (TTCT); **Selective Attention:** (1) Subtest Sky Search of the Test of Everyday Attention For Children (TEA-Ch)	Overall positive effect of selective attention on creativity measures, especially originality. Attention causes distractors to be ignored, ignoring new ideas, but it helps to focus on details, which is why it scores more in originality
Zhao et al. (2021)	China	**Study 1.** 73 students (M= 13.8; SD= 0.6) **Study 2.** 68 students (M=13.2; SD= 0.4) **Comparative and Experimental design**	**Study 1.** 13-15 years **Study 2.** 12-14 years	**Study 1.** **Working memory:** 4 tasks: 3 tasks to WM updating and 1 task WM span; **Inhibition:** (1) stroop task with Chinese character; (2) Flanker task; (3) GO/noGO; **Switching:** A digital test with a series of digits; **Creativity:** (1) Torrance Tests of Creative Thinking; (2) RAT (Chinese version. **Study 2.** **Pre- and Post-training Tests.** Working memory task, as described for Study 1, was used to assess near-transfer effects of the WM updating training; **Training Tasks.** Three adaptive running WM updating (a letter, animal, and visuospatial).	Creativity is related to working memory updating and not to inhibition, processing speed, working memory maintenance, or flexibility. This may be due to taking into account convergent thinking that other research does not value.
Chevalier et al. (2012)	USA	250 preschool children (1) M =3.71: age range = 3.67–3.83; (2) M= 4.45; age range = 4.42–4.5; (3) mean age 5.19; age range = 5.08–5.25) **Correlational design**	3 years 9 months, 4 years 6 months, and 5 years 3 months	**Flexibility:** (1) Shape School; **Inhibition:** (1) Go/No-Go task; **Working memory.** (1) The Nebraska Barnyard (adapted from the Noisy Book task)	Preschool-age children use working memory and inhibition to be flexible and creative. Students with greater inhibition are less flexible and concise, but this may be because at an early age it is more difficult to manage their cognitive abilities well.

3. Results

3.1. Main Methodological Characteristics

We begin by describing the bibliometric properties of the 12 studies included (Table 1), the general characteristics (Table 2) and then provide details on the relationship between the two variables (EFs and creativity).

Table 2. Systematic review sources: year, journal and language.

Variables	Frequencies	Percentage (%)
Year		
2012	1	8,3%
2017	1	8,3%
2018	1	8,3%
2019	1	8,3%
2020	4	33,3%
2021	4	33,3%
Journal		
Child Neuropsychology	1	8,3%
Developmental psychology	1	8,3%
Journal of Intelligence	3	25,0%
Memory and Cognition	1	8,3%
Personality and Individual Differences	1	8,3%
Psicogente	1	8,3%
Psychology of Aesthetics, creativity and the Arts	1	8,3%
Revista de Formación del Profesorado	1	8,3%
Thinking Skills and Creativity	1	8,3%
Trends in Neuroscience and Education	1	8,3%
Language		
English	10	83,3%
Spanish	2	16,7%

These 12 articles were published in 10 different journals, which are all indexed in JCR and/or SJR. The following table shows their general characteristics (Table 2).

Over the previous decade, research in relation to EFs and creativity in children has been very limited, but interest in the subject has increased in the last two years. In addition, certain relevant, interesting methodological characteristics help us understand the content of the selected articles (Table 3).

Table 3. Systematic review sources: sample and country

Variables	frequencies	Percentage (%)
Sample age		
Early childhood (0-6 years)	3	25,0%
Childhood (7-12 years)	7	53,8%
Adolescence (13-18 years)	2	23,1%
Country		
Argentina	3	25,0%
Canada	1	8,3%
China	1	8,3%
Netherlands	4	33,3%
Spain	1	8,3%
USA	2	16,7%

As the table indicates, childhood (7–12 years) has been examined most (n = 7), followed by early childhood (n = 3) and adolescence (n = 2). The 12 studies reported results from 6 countries, mostly the Netherlands (n = 4), Argentina (n = 3) and the USA (n = 2) and the remainder from Canada, China and Spain. The sample sizes varied, ranging from 64 to 289 students.

More than half of the studies (58.3%; n = 7) evaluated the three EFs that are considered fundamental (inhibition, working memory and shifting): 16.7% only looked at inhibition (n = 2); 8.3% investigated general EFs (n = 1); 8.3% explored inhibition and working memory (n = 1); 8.3% looked at attention (n = 1); and only 33.3% took into account the intelligence variable (n =4).

The studies reported using a variety of measurement approaches for the analysis of creativity: 41.7% evaluated verbal creativity (n = 5); 8.3% used figural or non-verbal creativity (n = 1); and 50% took into account both types of creativity (n = 6). The measures also varied in terms of the focus of analysis: 75.0% of the studies analyzed general creativity (n = 9), while fewer studies focused on creativity specific to some area, such as mathematical creativity (16.7%; n = 2) or reading and writing (8.3%; n = 1).

One important point is that all of the studies used performance and more than three-quarters of them used standardized tests to evaluate EFs (75%; n = 9) and creativity (83.3%; n = 10).

In general, analyzing the data indicates the large number of characteristics that encompass creativity and EFs, which explains the high variability in the measures used. EF and creativity are multifaceted constructs, and as such, there is no agreement on the elements

that make them up. This division into different threads can cause difficulties when analyzing and comparing them.

3.2. Relationship between EFs and Creativity

The first research question concerns the extent to which EFs and creativity are related. As previously mentioned, the literature presents different points of view about the relationship between EFs and creativity. In total, 33.3% of the 12 papers argued that inhibition correlated significantly with creativity; 25% stated that working memory and inhibition correlated with creativity; 16.6% related shifting and inhibition to creativity; 16.6% reported that attention correlated with creativity; and 8.3% related general EFs with creativity. Finally, two of the studies argued that working memory and inhibition did not correlate with creativity, claiming that only shifting did so.

On the one hand, in a sample of children ranging from 8 to 13 years old, Filippetti and Krumm [44] showed that working memory and inhibition together correlated significantly with creativity because they correlate with flexibility, and flexibility correlates with creativity when measured using TTCT [55] and CREA [56]. Similarly, in a sample of children with a mean age of 10.01 years, Krummet al. [9] reported thatworkingmemory, cognitive flexibility and inhibition measures with Stroop were significantly related to creativity measured in the same way. Chevalier et al. [54] reported that these same EF components also demonstrated a correlation with creativity in a sample of children aged 3 to 5 years old.

On the other hand, Sánchez Macías et al. [48] found positive, significant correlations between creativity measured with TTCT [55], flexibility and verbal inhibition but not with working memory in children aged 14–17; Zhao et al. [53] reported that creative thinking measured with TTCT [55] and RAT [57] was associated with working memory and inhibition but not with flexibility in a sample of children aged 12 to 15; additionally, Krumm et al. [47] found strong, significant correlations between creativity, which was measured using TTCT [55] and CREA [56], flexibility and inhibition, but it depended on intelligence and its control. Other authors found that creativity only correlated with inhibition or attention. For example, de Chantal and Markovits [46] reported that inhibition was positively related to creative thinking measured with an ad hoc test based on three different problems in a group of children aged 3 to 5 years old; Bai et al. [45] found that attention had a significant effect on originality in a sample of 5–7-year-old children; therefore, it has a significant effect on a component of creativity measured with AUT [17]; van Dijk et al. [52] also showed positive effects of selective attention abilities on creativity measured with AUT [17] and TTCT [55] in a sample with a mean age of 11.07 years.

Taking EFs as a general construct, Vaisarova and Carlson [51] reported that EF significantly predicted fluency and originality, showing a negative association between EF and AUT creativity scores for preschoolers (Adaptation ofWallach and Kogan's [58]) as well as scores in the adapted Montweiller and Taylor's test [59]. Specifically, in mathematical creativity, significant correlations were also found with inhibition [49,50], and correlations were even found with creativity in the general domain measured with TTCT.

In turn, some of these authors claimed that working memory and inhibition were not related to creativity [45] and some reported only relating inhibition and flexibility, not the other EFs [48].

3.3. Intelligence as a Mediating Variable

The second research question concerns the mediating effect of intelligence on this relationship. Four studies evaluated intelligence, but only one explained the importance of the construct in EFs and creativity. In fact, authors such as Filippetti and Krum [44] stated that people with high creativity showed greater flexibility without necessarily exhibiting higher intelligence. In another study, Krumm et al. [47] found that executive functions like inhibition and flexibility acted as mediators between creativity and fluid intelligence.

4. Discussion

The purpose of our study was to investigate how EFs relate to creativity and how these relationships are mediated by intelligence.

4.1. Relationship between EFs and Creativity

First of all, the review convincingly demonstrated that there is a relationship between flexibility and creativity. Many authors [3,9,44,48] positively correlated flexibility and negatively correlated inhibition with creativity. These correlations occur because a person with high flexibility and low inhibition shows a high creative capacity. These results are on similar lines as previous studies [26,30], which found positive relationships between flexibility, inhibition and creativity, proposing flexibility as the central factor.

On the other hand, there seems to be insufficient evidence for a relationship between creativity and EFs such as working memory [45]. These results are consistent with Sharma and Babu [28], who noted that previous research, such as Roskos-Ewoldsen et al. [60], showed that TTCT [55] is not demanding on working memory, leading to these results.

On similar lines, authors such as Bai et al. [45] and van Dijk et al. [52] noted that attention plays an important role in creative capacity measured with AUT [17]. This effect of attention was negative and indicates that children with a lower level of attention produce more original responses. This is in line with the findings of a series of recent studies on the role of

inhibition and attention, indicating that low inhibition and attention lead to higher creativity [27,37].

It is important to consider the variability in the tests used. Measures for creativity were relatively stable: TTCT [55], AUT [17] and CREA [56] were the most widely used. TTCT was used to assess figural creativity, AUT was used to assess verbal creativity and CREA was used to assess general creativity.

On the other hand, in EFs, there was a lot of variability in the tests, depending on the EF being evaluated (inhibition, flexibility or working memory). It is observed that only one study evaluates EFs in a general way with the Minnesota Executive Function Scale [61]. To measure the different EFs, we also find variability, but the most used tests are theWisconsin Card Sorting Test [62] and Five-Point Test [63] to measure flexibility, the WISC-IV digits subtest [64] to measure working memory and the STROOP test [65] for response inhibition. This indicates that there may be room for standardization of tests to measure children's EFs and creativity since the standardization of the measurement of these constructs would make it possible to generalize the results with greater rigor and reliability.

4.2. Intelligence as a Mediating Variable

All the studies analyzed in the present review used a measure of intelligence but only one examined what happens between intelligence, creativity and EFs. Intelligence seemed to play an important role in the samples of adults [1,26,37] but, in samples of children, there is not enough evidence to allow the results to be generalized. This means it is important to dedicate future efforts to studying this relationship in children and adolescents since most intelligence tests have a clear relationship with executive functions [66].

5. Conclusions

This study has important implications in the field of research on creativity and EFs, noting that creativity is not so much what children know (intelligence) but how they use that information, how they inhibit it and how flexible they are with it.

Society in the 21st century demands creative professionals who demonstrate leadership, planning and problem-solving skills. This is why, at an educational level, more and more active methodologies are used where creativity is worked on transversally [67]. This research supports the relationship between creativity and some EFs, and intends to promote future research to discover whether these constructs have a more specific relationship in children and adolescents, as is observed with a sample of adults.

The findings of this study indicate that educational interventions focused on cognitive training are needed to develop creative skills. This would also result in improvements in the

students' academic performance and in the development of skills they will need as future professionals. In practical terms, our results emphasize the importance of focusing on individual cognitive control, such as inhibition, flexibility and attention.

The present study has a number of limitations. The sample of articles was limited, although interest in this topic has increased in recent years. This indicates the importance of continuing to investigate the relationship between these two constructs. The measures of creativity tended to focus on divergent thinking and do not represent broader conceptions of creativity. This means that these measures may not be accurate and objective. Both creativity and executive functions are specific skills, meaning that they must be specifically measured. In addition, the variability of measures for executive functions does not allow a rigorous comparison between the studies since there were more than 30 different types of measures. Furthermore, the vast majority of the articles included in the study showed a trend towards positive results and there may be publication bias in this field. Lastly, in future studies, it could be important to analyze what happens with intelligence in relation to these two variables.

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ESTUDIO PUBLICADO 2:

Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity

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Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity

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ABSTRACT

Despite the importance of Executive functions, Divergent thinking, and intelligence in 21st century society, few studies have analyzed these variables in childhood and adolescence. The present study aimed to examine whether Executive functions and Divergent thinking have a developmental perspective and whether these variables predict intelligence. A non-clinical sample of 159 adolescents (78 girls and 81 boys) between 12 and 16 years of age (M=13.29 years; SD=1.17) participated in the study. Three tests were administered: (1) the Ice cream Virtual Reality Test to measure Executive functions; (2) the PIC-J to evaluate Divergent thinking; and (3) the WISC-V to measure cognitive variables. Executive functions were found to be developmental, as was verbal fluency as a creative component. However, only the Executive functions predicted intelligence. These findings provide information about how Executive functions develop and may contribute to helping develop students' talents. They also highlight the importance of learning more about Divergent thinking.

1. Introduction

Creativity is a dynamic cognitive process which includes the ability to generate new ideas or make new connections between existing ideas in order to adapt responses to different situations and develop innovative solutions (Guilford, 1967; Sternberg, 2020). Rooted in a combination of originality and practical value, creativity is a multifaceted construct that is vital for problem-solving and progress (Runco & Jagger, 2012).

The fundamental components of creativity are Divergent thinking (DT) and Convergent thinking (CT), characterized as pivotal processes of creative potential (Zhang et al., 2020). DT is recognized as a fundamental cognitive process that facilitates the generation of diverse sets of ideas. It operates by encouraging cognitive flexibility, breaking away from conventional thought patterns, and promoting the exploration of a wide range of potential solutions to open-ended problems (de Vries & Lubart, 2019; Goldschmidt, 2016). CT involves systematic evaluation of and convergence towards well-defined, optimal solutions from the pool of ideas produced during the divergent phase (de Vries & Lubart, 2019; Goldschmidt, 2016).

In the context of a process-oriented approach, creativity is often measured by tests based on components of DT, which is considered a key facet of creative potential and an integral step in the overall creative process (Lubart et al., 2013; Runco & Acar, 2012). These tests generally focus on four indicators: fluency, flexibility, originality and elaboration (Guilford, 1967; Runco & Acar, 2012). More specifically, flexibility refers to the capacity to create a varied range of distinctly different concepts, while fluency concerns the number of ideas produced. Originality is about on the uniqueness of concepts generated, and elaboration involves the ability to comprehensively expand and develop these concepts (Handayani et al., 2021; Hendrik et al., 2022).

Furthermore, DT can be assessed either through verbal or figurative production (Goff & Torrance, 2002). Figural DT can be assessed using drawing tasks, such as the Torrance Test of Creative Thinking-Figural (TTCT; Torrance, 1998) or the Test for Creative Thinking-Drawing Production (TCT-DP; Jellen & Urban, 1986). Verbal DT can be assessed in terms of fluency, flexibility, and narrative and verbal originality, for instance by using the Alternative Uses Task (AUT; Guilford, 1967; Guilford et al., 1978).

It is important to bear in mind that DT is expressed in different ways at each stage of development. Adolescents manifest DT differently to children or adults (Woodel-Johnson et al., 2012). In fact, various authors have stated that DT improves with age (Alacapinar, 2013; Hong & Milgram, 2010) and have found that creativity, in general terms, increases significantly

throughout schooling, although originality may decrease between 10 and 14 years of age (Claxton et al., 2005; Sali, 2015). On the other hand, Kleibeuker et al. (2016) argued that fluency and flexibility are fully developed in adolescence, but the quality of solutions and originality continue to develop into adulthood, with differences in the different components. Therefore, understanding the cognitive development of this variable is crucial (Vaisarova & Carlson, 2021).

Creativity can present different forms. In this regard, the creative cognition approach argues for the involvement of different cognitive processes within the creative process (Ferr´andiz et al., 2017; Ward, 2007). Considering the complex nature of DT, one of the cognitive processes that could play an important role is Executive functions (EF) (Benedek & Fink, 2019). EF are the cognitive capacities for effective, creative, socially accepted behavior (Lezak, 1982). They are also defined as the cognitive abilities that allow human beings to control and coordinate their goal-directed behaviors and thoughts (Carlson et al., 2013).

Various models have been proposed to describe EF. A review of the different models of EF (Tirapu et al., 2018) concluded that working memory, inhibition, shifting, verbal fluency and planning are the most commonly-found executive processes in the factorial models of EF in children and adolescents. More specifically, the processes of working memory and inhibition are present from an early age and are strongly correlated with each other—supporting a single factor structure that progressively diversifies with age—whereas shifting and verbal fluency processes emerge at school age, and planning appears towards pre-adolescence.

Along these lines, Miyake et al. (2000) presented a model by using multiple tasks to measure each component of EF and adopting a Latent Variable approach to extract the variance common to these tasks, assuming that by using multiple tasks, the factor common to these tasks would be a purer measure of EF. The main components related to EF are: inhibition, working memory, and shifting (Diamond, 2013; Lehto et al., 2003; Miyake et al., 2000). In our study, these components were selected rather than others because they are relatively simple to analyze and operationalize and, although clearly distinct, share underlying commonalities, as well as being related to other EFs such as planning, attention, switching and problem solving (Diamond, 2013; Miyake et al., 2000). However, this latent variable approach also has significant limitations related to the subjective interpretation of the latent factors, since the decision of how to define the latent factors lies with the researchers (Rosales et al., 2023).

Currently, there is an alternative approach called Network Models which does not involve researchers determining latent factors and is not constrained by the principle of local independence (Kan et al., 2019). However, it also has notable limitations because it only fits

well if the covariance between variables is large and when measurement error is small. Because of that, several researchers have opted for latent variable models over network models (Rosales et al., 2023).

The development of EF starts from the first year of life and continues to the end of adolescence and should be considered as different points in the maturation process (Cassandra & Reynolds, 2005). Authors such as Filippetti (2011) found that there might be a different pattern of development for the different executive domains: planning, working memory inhibition, verbal fluency and shifting. For example, working memory seems to follow a gradual course of development that begins in early childhood and continues through adolescence, shifting reaches adult-level performance at early ages of development, and planning ability remains relatively stable between the ages of 7 and 12.

Although studies such as Huizinga et al. (2006) maintained that the development of working memory continues into early adulthood, cognitive flexibility has been shown to gradually develop during middle childhood, continuing until adolescence. Finally, full development of planning is achieved in adolescence.

Proper development of EF is essential for the proper development of creativity. This means that successful performance of EF plays a crucial role in the production of innovative ideas, DT, and flexible adaptation, which are fundamental components of creativity (Krumm et al., 2018). In this regard, although there might be a clear connection between EF and DT in children and adolescents, different studies have produced varied results (Crenshaw & Miller, 2022; Palmiero et al., 2022). Shifting has been positively correlated with creativity, while inhibition has been negatively correlated (Pasarín-Lavín et al., 2023). Cognitive training programs that target working memory have shown beneficial effects on measures of DT, suggesting the possibility of a relationship in which working on one improves the other (Orzechowski et al., 2023). Additionally, Wang et al. (2021) indicated that EF such as inhibition and shifting were related to DT.

Furthermore, looking at variable predictiveness the outcomes are inconclusive. Authors such as Zabelina et al. (2019) indicated that EF, such as working memory and inhibition, predicted creativity depending on how creativity is defined: as DT or creative performance. Benedek et al. (2014) also found that updating and inhibition predicted creativity measured with 4 DT tasks.

These findings suggest that DT and EF contribute to each other's development. However, it is important to note that the relationship between creativity and EF might be

influenced by other components such as intelligence (Ardila, 2018). This relationship is still unclear and requires further investigation.

Krumm et al. (2018) indicated that there was evidence of a relationship between intelligence (fluid and crystallized), EF, and DT. Intelligence has been defined in various ways; in the development of intelligence scales, Wechsler (2014) identified a multiple intelligence component (Full Scale IQ). This was divided into five indexes, with the Verbal Comprehension Index (VCI) and the Fluid Reasoning Index (FRI) best reflecting the importance of fluid and crystallized capacities in this model.

In terms of the relationship between intelligence and EF, authors such as Benedek et al. (2014) reported that fluid intelligence was strongly predicted by EF such as working memory, but not by inhibition or shifting. This might be explained by the fact that, since intelligence is a multidimensional construct, intelligence tests might take advantage of other mental abilities such as working memory, processing speed, or attention (Arffa, 2007).

In contrast, Plucker and Esping (2015) outlined several perspectives on the relationship between DT and intelligence: (1) DT as a facet of intelligence; (2) DT as a result of intelligence, or (3) DT as a separate construct, sharing cognitive abilities with intelligence. Later, Plucker et al. (2020) suggested that intelligence and DT may be related but there are still no studies that fully demonstrate that. Other authors—such as Pan and Yu (2018), with a sample of 109 undergraduate students—have shown that intelligence has a positive relationship with originality as an element of DT. In addition, Silvia (2015) asserted that people who scored highly in intelligence tests also scored highly in creativity tasks, specifically DT tasks, and concluded that as current cognitive neuroscience suggests, DT and intelligence are linked although there is no real scientific evidence.

The relationship between intelligence and EF seems clearer, since intelligence tests usually involve different EF (Areces et al., 2018). In addition, some studies have focused on analyzing the relationship between VR-based Continuous Performance tests and Wechsler intelligence scale components (Areces et al., 2018; Krch et al., 2013). Along these lines, Areces et al. (2018) showed that students with EF deficits had lower scores in working memory and processing speed, as well as exhibiting poorer performance in EF assessed via VR in comparison to their peers without EF difficulties.

On the other hand, the relationship between intelligence and DT is not so clear since there are very few empirical studies, and what has been reported is sometimes contradictory (Plucker & Esping, 2015; Silvia, 2015, Vaisarova & Carlson, 2021). However, it is interesting to analyze whether DT also predicts intelligence, looking at creativity as an emerging and less

researched construct in this field. For example, Frith et al. (2021) focused on executive capacity as a mediator between fluid intelligence and creative potential measured as DT, considering inhibition and working memory.

However, the development of DT and EF in childhood and adolescence, as well as their interrelation with other factors like intelligence, is important for appropriate educational interventions. Studies in this field should also consider how these components develop over time, adopting developmental perspectives.

Interest in the variables in the present study is due to how important they are in today's society, and this means that they need to be thoroughly understood from childhood onwards. However, there are as yet few studies that have looked at this relationship in children or adolescents (Benedek et al., 2014; Bernabeu-Brotons et al., 2021; Pan & Yu, 2018). In addition, as both DT and EF develop during childhood and adolescence, and may have a different relationship than in adults (Krumm et al., 2020). Finally, using a VR-based tool to measure EF might provide ecological validity to the research while offering an innovative approach to the study of this relationship.

2. The present study

The present study examines the relationships between EF, creativity (assessed with two measures of DT) and intelligence, aiming to show the developmental character of EF and creativity and how predictive they are of intelligence. This overall goal includes two specific objectives:

O1. Analyze EF and creativity considering a developmental perspective.

O2. Analyze the predictive nature of EF and creativity in intelligence.

Based on previous research (Cassandra & Reynolds, 2005; Kaufman & Beghetto, 2009), EF and creativity will probably improve as children move up through school years, in other words, these variables are developmental. Similarly, as Plucker et al. (2020) and Ardila (2018) suggested, EF and creativity are expected to predict intelligence.

3. Method

3.1. Participants

The initial sample consisted of 182 high school students. Based on the data provided by the school, the inclusion criteria included: (1) children without special needs; (2) in the 1st to 4th year of secondary education; (3) who attend school regularly. Based on these criteria, 23 students with SEN were excluded from the sample. The final sample consisted of 159 secondary-school students from the north of Spain (78 girls and 81 boys; M = 13.29 years; SD = 1.17 years; range from 12 to 16 years). The sample was split into four groups based on the

school year: 1st year (*n* = 55); 2nd year (*n* = 58); 3rd year (*n* = 13); 4th year (*n* = 33). Following an intelligence assessment, 62.3% demonstrated an average IQ (90-109), 15.7% a high average IQ (110-119), 10.1% a very high IQ (120-129); 8.2% a low average IQ (80-89); and 3.8% a very low IQ (70-79). Table 1 shows the demographic characteristics of the sample. There were no significant differences between IQ (p = .512) or gender ($x2$ = ,057; df = 1; p = .812).

Table 1.

Demographic characteristics of the sample

Groups		Gender		Age		FSIQ		VCI		FRI	
	n	*M*	*F*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
1st year	55	26	29	12.15	.488	101.49	11.60	104.83	12.67	97.26	13.16
2nd year	58	27	31	13.16	365	101.20	11.02	105.76	12.47	94.67	15.60
3rd year	13	7	6	14.08	.277	107.08	11.13	113.77	7.40	104.61	12.29
4th year	33	21	12	15.12	.331	102.99	12.92	107.90	14.54	98.19	12.06
Total	159	81	78	13.29	1.17	102.15	11.65	106.80	12.80	97.11	13.96

Note. FSIQ (Full Scale IQ); VCI (Verbal Comprehension Index); FRI (Fluid Reasoning Index); M= Mean; SD=Standard deviation.

3.2. Instruments and measures

3.2.1. Measures of Executive functions

Nesplora Executive Functions - Ice Cream measures various components of EF and learning in children from 8 years old through an immersive experience with VR.

The test is a 20-45 minute recreation of a realistic multitasking environment based on the premise "it's your first day at work in an ice cream shop". Various rules must be followed and objectives met in order to complete the challenges presented. The ecological validity of this test allows EF to be measured, maximizing the predictive value of the real functional performance of the person being evaluated. *Nesplora Executive functions - Ice Cream* has some special features that make it seem more like an "adaptive" test, therefore it has very good ecological validity, but in addition, all the main test variables show reliability via McDonald's Omega coefficients of between .85 and .97 (Fernandez et al., 2023).

The test measures the EFs *planning, working memory, processing speed* and *cognitive flexibility.* Miyake's model is mentioned above as a basic theoretical model, but inhibition was not included as a measurement variable because of the characteristics of the test.

3.2.2. Measures of Divergent thinking

PIC-J. Prueba de Imaginación Creativa para Jóvenes- Creative Imagination Test for Young People (Artola et al. 2008) is a test to evaluate creativity, measured as DT, in subjects between 12 and 18 years old through their use of imagination. It consists of four games: three assess verbal or narrative creativity, while the fourth assesses graphic creativity. Game 2 and

game 4 were used for the study. Game 2 involves a test of possible uses of an object to assess *Verbal Fluency*, *Verbal Flexibility* and *Verbal Originality*. Game 4 uses a graphical imagination test inspired by the Torrance Test of Creative Thinking (TTCT; Torrance, 1998) to assess *Figural creativity* based on the dimensions of *Originality* and *Elaboration*. It includes the variables *Title* and *Graphic Details*. The test's psychometric properties and reliability were checked by the authors, giving a Cronbach's Alpha for the test set of .85

PIC-J Interrater Agreement. One of the most significant problems in creativity tests is the difficulty for two raters to produce equivalent scores. For this reason, interrater agreement was used to check the validation of the scoring of the PIC-J. The degree of agreement was calculated using Cohen's weighted kappa statistic (*k*). Landis and Koch (1977) suggested an interpretation as follows: values ≤ _0 as poor; 0.00 – _0.20 as slight, 0.21 – _0.40 as fair, 0.41 – _0.60 as moderate, 0.61 – _0.80 as substantial, and 0.81–1.00 as almost perfect agreement.

Implementing Cohen's Kappa involved the following considerations: (1) there are two raters who analyze at least 25% of the sample; (2) they have the same instructions and criteria for rating; and (3) the items to be rated are independent. In the initial comparison, the *k* value was slight in several variables, with the highest values in *Verbal Fluency (*substantial, > 0.61), *Verbal Flexibility* (moderate, > 0.41) and *Graphic Details* (moderate, > 0.41). Twenty more subjects were evaluated after discussion and agreement between raters, producing *k* values that were almost perfect (*Verbal Fluency* and *Figural Elaboration*, > 0.81) and substantial (*Verbal Flexibility, Verbal Originality, Figural Originality, Figural Title and Graphic Details*, > 0.61).

3.2.3. Measures of Intelligence

The Spanish adaptation of the WISC-V (Wechsler, 2014) was used in this study. The internal consistency of the Spanish adaptation of the WISC-V has been examined using the two-half method. The reliability of the IQ (FSIQ) is 0.95 (Amador & Forns, 2019).

In this study, the 7 main measurements used to obtain *Full Scale IQ (FSIQ)* were: Similarities and Vocabulary for Verbal Comprehension; Block Design for Visual Spatial; Matrix Reasoning and Weights for Fluid Reasoning; Digit Span for Working Memory; and Symbol Research for Processing Speed. These measures produced the *Verbal Comprehension Index* (VCI) and the *Fluid Reasoning Index* (FRI).

3.3. Procedure

The study was conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki), which reflects the ethical principles for research involving humans (World Medical Association, 2013). The study was approved by the Ethics Committee of the Principality of Asturias (reference: CEISH-UPV/EHU, BOPV 32) and all

procedures were in compliance with relevant laws and institutional guidelines. Data were collected from children, schools and parents.

All parents received notice requesting informed consent which described the aims of the study and had to be signed before the study began.

EF was assessed by a psychologist specializing in using the tool, in groups of 5 students due to the nature of the test—an immersive experience with VR. Assessment of DT and intelligence was performed individually by four specialists in educational psychology from the University of Oviedo who had been previously trained in the use of the tests. The professionals underwent two training sessions. The initial session introduced participants to the WISC-V and PIC-J tests, as well as ethical considerations for applying them. The second session provided opportunities to practice applying the concepts and interpreting the results.

The tests were carried out over two weeks in each school, with a maximum of one day between the two tests for each student.

The students were naturally organized by school year and the sampling was by accessibility. Participants did not receive any reinforcement/rewards for participation. The order of the tests was randomized in the sample, one part of the group did the intelligence and DT test first and the other part of the group did the EF test and vice versa. The total evaluation for each subject lasted two and a half hours split into two sessions.

3.4. Data analysis

Statistical analyses were performed using SPSS 27.0. First, descriptive statistics for the variables were calculated (see Table 1) and the indicators of sample normality (kurtosis and skewness) were examined. The effect of gender and intelligence on the dependent variables was assessed. Subsequently, parametric analysis was performed via analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) to determine the developmental perspective of EF and DT. Differences were considered as statistically significant at a level of $p \leq 0.05$. In order to identify the differences between the groups, *Sheff´e* multiple comparisons were used. Effect sizes were calculated using *partial eta squared* (*ηp2*) following *Cohen's d* criteria (1988).

Finally, hierarchical regression analysis was conducted to predict the influence of those variables on intelligence. The first model included the effect of age and gender, the second model added EF variables, while the third model added DT variables.

4. Results

4.1. Initial analysis

Considering Finney and DiStefano (2006), the values for *skewness* and *kurtosis* indicated that all of the data were normally distributed (see Table 2), hence the data were analyzed through parametric analysis.

Table 2.
Descriptive statistics

Variables	Total (*n*=159)	Secondary school year			
		1st year (*n*=55)	2nd year (*n*=58)	3rd year (*n*=13)	4th year (*n*=33)
DT					
Verbal fluency					
M(SD)	8.89(4.93)	7.44(5.08)	9.59(4.52)	9.46(4.79)	9.85(5.06)
Kurtosis	1.39	6.10	-.708	3.31	-.023
Skewness	1.03	2.08	.290	1.78	-619
Verbal flexibility					
M(SD)	6.37(2.85)	5.25(2.77)	6.91(2.72)	7.39(2.81)	6.89(2.76)
Kurtosis	-.504	1.13	-.728	-.028	-.571
Skewness	.227	.915	-.192	.859	-.130
Verbal originality					
M(SD)	7.17(5.14)	5.50(4.57)	7.93(5.18)	8.46(4.43)	8.11(5.70)
Kurtosis	.691	2.08	-.250	.612	1.41
Skewness	1.07	1.43	.196	1.23	1.20
Figural originality					
M(SD)	4.78(2.41)	4.37(2.37)	5.09(2.27)	5.46(2.88)	4.66(2.48)
Kurtosis	-.445	-.348	-.250	-.797	-.610
Skewness	.265	.362	.196	.445	.132
Figural elaboration					
M(SD)	.884(1.27)	.831(1.08)	.88(1.31)	.846(1.41)	.996(1.46)
Kurtosis	4.48	.397	6.96	6.79	3.60
Skewness	1.88	1.17	2.16	2.45	1.88
Figural title					
M(SD)	1.67(1.80)	1.62(1.70)	1.35(1.56)	3.46(2.57)	1.62(1.69)
Kurtosis	.145	.257	.668	-1.52	.205
Skewness	.975	.883	1.17	-.226	.929
Graphic details					
M(SD)	.443(.731)	.362(.641)	.397(.699)	.846(1.07)	.499(.750)
Kurtosis	1.95	4.83	.787	-.705	2.78
Skewness	1.63	2.07	1.59	.838	1.66

Variables	Total (*n*=159)	Secondary school year			
		1st year (*n*=55)	2nd year (*n*=58)	3rd year (*n*=13)	4th year (*n*=33)
EF					
Planning					
M(SD)	10.15(3.82)	8.37(3.92)	11.07(3.15)	11.39(2.96)	11.007(4.10)
Kurtosis	-.675	-1.36	1.56	-.706	.237
Skewness	-.810	-.071	-1.49	-.924	-1.31
Working Memory					
M(SD)	46.83(6.83)	45.49(6.38)	46.23(7.22)	47.46(9.40)	49.85(4.72)
Kurtosis	.352	-.557	-.091	2.41	1.11
Skewness	-.878	-.460	-.743	-1.69	-.926
Flexibility Interference					
M(SD)	14.06(19.35)	15.75(21.53)	13.77(17.79)	23.00(27.17)	8.20(12.41)
Kurtosis	3.95	3.74	3.03	2.14	-.559
Skewness	1.61	1.47	1.42	1.50	.757
Flexibility Perseverance					
M(SD)	1.25(1.80)	1.36(1.79)	1.42(2.01)	1.46(2.18)	.693(1.06)
Kurtosis	5.05	8.18	2.77	2.29	4.04
Skewness	2.14	2.55	1.78	1.62	1.97

Note. EF= Executive functions DT= Divergent thinking; M= Mean; SD=Standard deviation

As Table 3 shows, there was significant correlation between most of the variables. In some cases, this correlation was not positive, such as *figural originality* with almost all variables (except figural elaboration and planning), and *verbal originality* with *figural elaboration* and *graphic details*, among others.

Table 3.

Pearson Correlations for EF and DT variables

1	1	2	3	4	5	6	7	8	9	10	11
1.VFLU	—										
2. VFLE	.31**	—									
3.VOR	.15*	.11	—								
4.FOR	.20**	.28**	.11	—							
5.FEL	.23**	.06	.25**	.19**	—						
6.FTIT	.14*	-.15*	.16*	.08	.79**	—					
7.GDET	.04	.05	.21**	.05	.66**	.37**	—				
8.PLAN	.31**	.32**	.25**	.30**	.74**	.41**	.26**	—			
9.WM	.03	-.17*	.02	.01	.49**	.37**	.31**	.15*	—		
10.FINT	-.06	.17*	.03	.06	-.36**	-.37**	-.17*	-.22**	-.28**	—	
11. FPER	-.09	.18**	.10	.04	-.27**	-.33**	-.08	-.14*	-.27**	.78**	—

Note. VFLU=Verbal Fluency; VLE=Verbal Flexibility; VOR=Verbal Originality; FOR=Figural Originality; FEL=Figural Elaboration; FTIT= Figural Title; GDET= Graphic Details; PLAN=Planning; WM=Working Memory; FINT= Flexibility Interference; FPER=Flexibility Perseverance.
*$p < .05$; **$p < .01$.

4.2. Executive functions and Divergent thinking

MANOVA analysis with gender indicated that there were no statistically significant differences for divergent thinking ($p = .563$) or EF ($p = .160$) variables according to gender.

Table 4.

DT and EF descriptive statistics by gender and year groups

	TOTAL		**1st year**		**2nd year**		**3rd year**		**4th year**	
	M	F	M	F	M	F	M	F	M	F
DT										
VFLU	9.48 (5.18)	8.27 (4.60)	7.93 (5.47)	7.00 (4.77)	10.52 (4.71)	8.77 (4.26)	11.57 (5.56)	7.00 (2.10)	9.38 (5.05)	10.68 (5.17)
VFLE	6.71 (2.81)	6.02 (2.86)	5.60 (2.72)	4.93 (2.81)	7.33 (2.50)	6.55 (2.90)	8.43 (2.88)	6.17 (2.40)	6.71 (2.94)	7.21 (2.50)
VOR	7.66 (5.18)	6.66 (5.08)	5.87 (4.98)	5.17 (4.23)	8.85 (5.30)	7.13 (5.02)	9.86 (5.21)	6.83 (2.93)	7.62 (4.89)	8.97 (7.05)
FOR	4.88 (2.36)	4.68 (2.46)	4.71 (2.14)	4.07 (2.55)	4.93 (2.50)	5.23 (2.09)	5.29 (3.25)	5.67 (2.66)	4.91 (2.28)	4.23 (2.86)
FEL	.959 (1.37)	.806 (1.15)	.950 (1.22)	.724 (.960)	.963 (1.63)	.806 (.981)	1.43 (1.72)	.167 (.408)	.810 (1.12)	1.32 (1.93)
FTIT	1.60 (1.68)	1.75 (1.93)	1.62 (1.35)	1.62 (1.99)	1.15 (1.26)	1.52 (1.79)	4.00 (2.71)	2.83 (2.48)	1.33 (1.56)	2.13 (1.86)
GDET	.468 (.772)	.416 (.690)	.420 (.796)	.310 (.471)	.370 (688)	.419 (.720)	1.28 (1.25)	.333 (.516)	.381 (.498)	.706 (1.05)
EF										
PLAN	10.29 (3.77)	9.99 (3.89)	8.77 (3.59)	8.00 (4.22)	11.57 (3.04)	10.63 (3.24)	10.57 (3.74)	12.33 (1.51)	10.43 (4.39)	12.02 (3.48)
WM	46.40 (7.43)	47.26 (6.16)	43.83 (6.30)	46.98 (6.18)	46.49 (8.70)	46.01 (5.77)	45.14 (10.14)	50.17 (8.52)	49.91 (4.45)	49.74 (5.36)
FINT	15.38 (21.67)	12.68 (16.64)	21.30 (26.61)	10.78 (14.41)	10.82 (14.21)	16.34 (20.28)	37.00 (30.40)	6.67 (8.21)	6.71 (11.75)	10.79 (13.62)
FPER	1.47 (2.11)	1.03 (1.38)	1.86 (2.32)	.911 (.944)	1.42 (2.29)	1.43 (1.77)	2.57 (2.51)	.167 (.408)	.667 (1.02)	.739 (1.19)

Note. VFLU=Verbal fluency; VLE=Verbal flexibility; VOR=Verbal originality; FOR=Figural originality; FEL=Figural elaboration; FTIT= Figural title; GDET= Graphic details; EF=Executive functions; DT= Divergent thinking; PLAN=Planning; WM=Working memory; FINT= Flexibility interference; FPER=Flexibility perseverance; M=Masculine; F=Feminine.
* *p<.05*

Secondly, MANOVA analysis with year groups showed statistically significant differences for DT (λ _= .765; $F(3,158) = 1.992$; $p < .001$; $\eta p2 = .085$) and for EF (λ _= .807; $F(3,158) = 2.824$; $p < .001$; $\eta p2 = .069$).

Inter-subject effects indicated statistically significant differences between year groups in the EF variables *planning (F(3,158)* = 6.781; $p < .001$; ηp^2 = .116), and *working memory* (*F(3,158)* = 3,162; p = .026; ηp^2 = 0.58), and the DT variables *verbal flexibility* (*F (3,158)* = 4,806; p = .003; ηp^2 = 0.85), *verbal originality* (*F(3,158)* = 3,118; p = .028; ηp^2 = 0.57), and *graphic title* (*F(3,158)* = 5,325; p = .002; ηp^2 = 0.93).

A deeper analysis of the development of EF and DT considering the groups using the Scheff´e *post-hoc* test with different variables showed that there were differences between 1st, 2nd and 4th years in *planning* (p = .003); between 1st and 4th years in *working memory* (p = .017); and between 1st and 2nd years in *verbal flexibility* (p = .018).

Finally, interactions between gender and year group also indicated no statistically significant differences for DT (p = .625) or EF (p = .124) variables by group.

4.3. Involvement of Executive functions and Divergent thinking in intelligence

A hierarchical regression analysis was performed to predict the influence of EF and creativity on intelligence, considering intelligence as a general scale (FSIQ) and its two indexes of *verbal comprehension* (CVI) and *fluent reasoning* (RFI).

FSIQ regression showed that model 2 gave the highest percentage of explained variance, when the model included EF, with *working memory* and *interference flexibility* being significant.

Similarly, CVI regression indicated that models 2 and 3 were significant when the model included EF, with gender and *planning* being significant. Subsequently adding the DT variables increased the explained variance with gender, *planning* and *figural title* being significant.

Finally, FRI regression demonstrated that none of the models was significant, although some specific variables were (e.g. *flexibility interference* in model 2 and model 3).

Table 5.

Hierarchical regression analysis models to predict intelligence influence

		FSIQ	CVI	FRI
Model 1	Gender ß (*t*)	-.114 (-1.43)	-.181 (-2.295*)	-.180 (-2.282*)
	Age ß (*t*)	.023 (.283)	.057 (.723)	.034 (.428)
	R^2	.014	.038	.035
Model 2	Gender ß (*t*)	-.116 (-1,486)	-.175 (-2.274*)	-.178 (2.257*)
	Age ß (*t*)	-.044 (-.542)	-.020 (-.249)	.003 (.041)
	Planning ß (*t*)	.131 (1.575)	.245 (3.007**)	.036 (.424)
	Working Memory ß (*t*)	.237 (2.299*)	.143 (1.413)	.195 (1.884)
	Flex. Interference ß (*t*)	.211 (1.993*)	.132 (1.266)	.223 (2.088*)
	Flex. Perseverance ß (*t*)	-.013 (-.111)	.022 (.200)	.001 (.008)
	R^2	.091*	.125**	.080
	$\triangle R2$	,077	.087	.046
Model 3	Gender ß (*t*)	-.109 (-1.391)	-.174 (-2.324*)	-.181 (-2.274*)
	Age ß (*t*)	-.069 (-.838)	-.046 (-.586)	-.012 (-.160)
	Planning ß (*t*)	.118 (1.407)	.227 (2.832**)	.041 (.481)
	Working Memory ß (*t*)	.197 (1.871)	.108 (1.073)	.194 (1.819)
	Flex. Interference ß (*t*)	.183 (1.720)	.099 (.970)	.218 (2.014*)
	Flex. Perseverance ß (*t*)	-.008 (-.065)	.056 (.511)	.033 (.282)
	Verbal Fluency ß (*t*)	-.109 (-.556)	-.158 (-.843)	-.321 (-1.613)
	Verbal Flexibility ß (*t*)	.226 (1.268)	.175 (1.030)	.259 (1.431)
	Verbal Originality ß (*t*)	-.023 (-.169)	.118 (.907)	.095 (.683)
	Figural Originality ß (*t*)	-.034 (-.412)	-.075 (-.940)	-.107 (-1.269)
	Figural Elaboration ß (*t*)	.048 (.561)	-.027 (-.326)	-.012 (-.134)
	Figural Title ß (*t*)	.148 (1.690)	.257 (3.079**)	.096 (1.085)
	Graphic Details ß (*t*)	.051 (.609)	.058 (.723)	.074 (.878)
	R^2	.145	.221*	.120
	$\triangle R2$	.054	.096	.040

Note. FISQ= Full Scale IQ; CVI= Comprehension Verbal Index; FRI= Fluid Reasoning Index; ß = Standardized beta coefficient; t = Student t coefficient; *R2* = Variance explained; $\triangle R2$ = Change in variance explained.
* $p < 0.05$; ** $p < 0.01$; ***, $p < 0.001$.

5. Discussion

5.1. Developmental perspective of Executive functions and Divergent thinking

The results suggest that EF such as planning and working memory are developmental. More specifically, there was an increase in scores from 1st year to 4th year. This is consistent with Davidson et al. (2006), who noted that until the age of 19, EF such as cognitive flexibility may not be fully developed. However, it contradicts Filippetti (2011), who indicated that cognitive flexibility, working memory and verbal fluency develop with age but planning does not. This may be because different age ranges were evaluated, but not many studies have looked at this progression, perhaps because of the relationship between WISC-V and EF variables, seeing as how all of the WISC-V subtests evaluate some of these (planning, working memory, processing speed, etc.).

There was a different result for DT, with levels of verbal variables such as verbal DT, verbal originality, and graphic title being maintained. However, figural DT demonstrated a downward trend as schooling progressed. This contradicts the results from Hong and Milgram. (2010), noting the development of creativity, measured as DT, throughout children's development. This may be because adolescents have developed verbal fluency, but the quality of their responses continue to improve as they learn new knowledge, skills, and aptitudes. Adolescents can make associations, but it is a skill that is fully developed in late adolescence (Kleibeuker et al., 2016).

Creative processes are expressed in different ways in each of the developmental stages, with adolescents expressing creativity differently from children or adults (Woodel-Johnson et al., 2012). This is why there were clear differences between 12-year-old students and 16-year-old students and why there are no studies that demonstrate a clear interrelationship between age and creativity (Revuelta et al., 2022).

5.2. Predictive value of variables related to Executive functions and Divergent thinking on intelligence

As previous studies have reported, EF had a clear predictive relationship with intelligence. In particular, cognitive flexibility and working memory are more clearly consistent with Ardila (2018) and Benedek et al. (2014). Arya and Maurya (2016) stated that this may be because schools today contribute to the development of intelligence but hardly at all to creativity.

In contrast, DT could not be shown to predict intelligence. These results are consistent with Silvia (2015) who found no evidence for it. A nonlinear relationship between DT and cognitive abilities, such as intelligence, was asserted by some early theorists (e.g. Guilford, 1967). Creativity, despite being a necessary skill for 21st century education, is still an open, controversial field (Runco, 2014).

Researchers such as Plucker et al. (2020) believed that intelligence and DT may be related but there are still no studies that fully demonstrate this. For example, Pan and Yu (2018) analyzed a sample of 109 undergraduate students and showed that intelligence had a positive relationship with originality as an element of DT. Following a study with 242 students between the ages of 18 and 19, Silvia (2008) noted that previous research had likely underestimated the DT-intelligence relationship. Along similar lines, Silvia (2015) noted that people who scored highly in intelligence tests also scored highly in creative tasks—measured as DT—and concluded that current cognitive neuroscience implies that creativity and intelligence are linked although there is no real scientific evidence.

When EF variables were included, the regression model was significant and therefore predicted intelligence. These results are consistent with Ardila (2018) and Benedek et al., (2014) indicating that that some EF correspond to intelligence, especially the more intellectual functions such as working memory, planning, and attention.

On the other hand, the model was only significant in the verbal comprehension index when DT variables were included. This is consistent with Benedek et al. (2014), who noted that the relationship between DT and intelligence had to do with EF and verbal fluency. According to Amunts et al. (2020), verbal fluency could be considered a component of EF, or at least be strongly related. These results show that EF development can help the creative process, especially at the verbal level of DT, during the evaluation phase (Beaty et al., 2014, Krumm et al., 2018).

6. Conclusions and Limitations

Understanding the relationship between DT, EF, intelligence, and learning requires combined contributions from neuropsychology and education. In this regard, one of the main practical implications of this study for education is that it indicates that the development of these skills should be promoted at school since they have a direct relationship with intellectual ability. Promoting EF at school could help produce more talented students, with greater verbal intelligence and fluid reasoning, and could therefore make them more creative.

As for creativity, it is important to consider it a construct yet to be discovered and, because of the variability and subjectivity of the evaluation tests, no real conclusions can be reached. In this regard, our study is a small contribution that can help us understand how important variables like DT are related at the educational level.

However, the study does have some limitations that must be considered in future research. The sample size of some of the groups may limit the generalizability of the results. It might be interesting to add a sample of students with special educational needs (SEN) to compare the progression in these variables in students with different needs.

Finally, one future line of research would be to test the relationship between the variables described here (EF and DT), considering other EF such as inhibition and other types of creative thinking such as CT. In addition, it is crucial to further investigate the potential of VR tools in assessing and intervening in cognitive processes, such as EF. It would also be interesting to carry out a cross-cultural study to analyze the progression of these variables in other cultures where different educational systems promote them to different extents. This would help us to highlight the need for schools to work on EF in order to improve not only students' _creativity but also their skills. Furthermore, it would be interesting to carry out a

comparative study of these variables in normotypical samples, with educational needs, and with medical conditions (García et al., 2014; Lonergan et al., 2019; Operto et al., 2020) (Tables 4 and 5).

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CRediT authorship contribution statement

Tania Pasarín-Lavín: Writing – _original draft, Methodology, Data curation, Conceptualization. **Trinidad García:** Project administration, Methodology, Funding acquisition, Formal analysis. **Celestino Rodríguez:** Supervision, Project administration, Funding acquisition. **José Carlos Núñez:** Writing – _review & editing, Visualization. **Débora Areces:** Writing – _review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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ESTUDIO PUBLICADO 3:

Neurodivergent Students. A Continuum of Skills with an Emphasis on Creativity and Executive Functions

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Neurodivergent students. A continuum of skills with an emphasis on creativity and executive functions

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ABSTRACT

This study analyses Executive Functions (EF) and Creativity among neurodivergent students -including students with Attention Deficit Hyperactivity Disorder (ADHD), Dyslexia, Intellectual Disability (ID), Giftedness-, and a group with Neurotypical development. A sample of 181 secondary school students participated in the study. Creativity was assessed by using the PIC-J test, focusing on verbal and figural components of divergent thinking, while EF were evaluated through Nesplora Ice-Cream, a virtual reality tool assessing flexibility, working memory, and inhibition. Results showed statistically significant differences in Verbal Creativity, especially in Originality: students with ADHD outperformed their Neurotypical peers, while those with ID showed the lowest scores. Although no statistically significant differences emerged in Figural Creativity, students with ADHD showed the lowest scores in Elaboration or Figural details, whereas those with Dyslexia exhibited high levels of Figural Originality, similar to their Neurotypical peers. Concerning EF, students with ID had the highest scores in Interference and Perseveration, indicating poorer Flexibility. In contrast, Gifted students performed better than the other groups in Working Memory, while students with ADHD did not exhibit special difficulties in EF. These findings emphasize the importance of personalized interventions for Neurodivergent students, that recognize and capitalize on their unique strengths while addressing specific challenges.

KEYWORDS

Creativity; executive functions; neurodivergence; neurodiversity; special educational needs

Introduction

Neurodiversity is a concept that highlights the value of neurological differences in the human population (McGee, 2012). This term has gained significant attention in the field of educational psychology, particularly in relation to neurodiverse learners or those who show different learning profiles due to their divergent rates of learning, including students with Attention Deficit Hyperactivity Disorder (ADHD), Dyslexia, and Intellectual Disabilities (ID) (Armstrong, 2010; Clouder et al., 2020). All of these groups are categorized as "Neurodevelopmental Disorders" in the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM–5; American Psychiatric Association [APA], 2013), although reading difficulties are categorized under the more general diagnosis of Specific Learning Disorder. While Gifted students are generally considered to be a group without specific deficits, at least at a cognitive level, there are studies (Bergold et al., 2020; Mammadov et al., 2021) arguing that this type of student does not necessarily have to demonstrate excellent development and performance in all areas, but that they may have problems with motivation, low performance, and integration, among others. From this viewpoint, they could also be characterized as neurodiverse students.

As mentioned above, all of these students have diverse neurodevelopmental profiles, which bring a rich context of cognitive strengths and challenges to the educational field (Sewell & Park, 2021). Overall, they are recognized as having Special Educational Needs (SEN) within the educational field. However, there are many particularities within this group.

One important part of this diversity comes from two important cognitive aspects, Executive Functions (EF) and Creativity. By exploring the intricacies of SEN and acknowledging the influence of EF and Creativity in neurodiverse learners, we can promote a more comprehensive psychoeducational approach that acknowledges and facilitates the distinctive strengths and potential of all learners.

Special Education Needs (SEN) and Neurodivergence

The neurodiversity paradigm provides a psychological framework for understanding and addressing the educational requirements of diverse learners. This approach, in contrast to traditional SEN models, emphasizes an inclusive approach to identification, teaching, and learning (Griffiths, 2020). The neurodiversity perspective challenges the traditional deficit- or pathology-based frameworks that have shaped our understanding of diverse learning profiles. It is based on recognition of individual strengths and needs (Banks, 2014) rather than focusing

solely on deficits or limitations. Within the neurodiversity paradigm, students with different neurological profiles, including conditions such as ADHD, Dyslexia, ID and Giftedness, are seen as having unique cognitive strengths and perspectives that contribute to the richness of human diversity (Armstrong, 2012; Sewell & Park, 2021).

The neurodiversity perspective recognizes variations in cognitive and psychological functioning, offering a holistic intervention approach that appreciates each learner's unique strengths and challenges (Shaughnessy, 2022). Studies within this perspective suggest that individuals who are neurodiverse may possess strong skills in areas such as executive functions, creativity, or spatial visualization skills (Rentenbach et al., 2017; Syharat et al., 2023).

However, they may also encounter challenges in conventional settings. That is why it is important to explore the experiences of learners with neurodiverse conditions within the framework of developmental psychology and education. This approach can help identify the challenges they may face and the support systems they need to enhance their personal and educational development (Dwyer, 2022).

Although support services and technologies are available to meet the specific needs of all students, assessment, intervention, and pedagogy are often designed for Neurotypical Students. This is because they are anchored in a traditional deficit and pathology-based perspective (Clouder et al., 2020). It is important to note that this approach may not be suitable for all students, and therefore alternative approaches must be considered, especially those that are more inclusive and pay attention to the diverse needs of students (Tomlinson, 2014). This will help teachers and psychologists to better identify a student's characteristics and properly target assessment and intervention (Pasarín-Lavín et al., 2023).

Creativity and Executive Functions in Neurodivergent Students

As mentioned above, neurodiverse students may present different strengths and deficits in components such as Creativity and EF. Creativity is a highly valued skill in modern society due to its impact on progress (Bonetto et al., 2021; Runco & Pritzker, 2020). It is a multifaceted, dynamic phenomenon that is crucial to innovation and adaptability, often characterized as the aptitude for generating innovative and practical solutions (Guilford, 1967; Said-Metwaly et al., 2018; Sternberg, 2020). This definition of Creativity is intimately linked to the concept of Divergent Thinking (DT), which plays a key role in fostering creativity and is the ability to generate multiple, varied solutions to a given problem, often deviating from conventional or

linear patterns of thinking (de Vries & Lubart, 2019). DT encompasses both verbal and figural production, where individuals can show the expression of their innovative ideas through linguistic means such as the Torrance Test of Creative Thinking-Figural (TTCT; Torrance, 1998); or graphical means (Figural) such as the Alternative Uses Task (AUT; Guilford, 1967; Guilford et al., 1978).

Conversely, EF are a collection of advanced cognitive processes responsible for regulating, organizing, and controlling cognitive and behavioral activities (Cristofori, 2019). These functions involve abilities such as working memory, planning, inhibition and cognitive flexibility (Diamond, 2013).

Scientific research has contributed to the discourse on Creativity, innovation and EF. Studies in the field of cognitive psychology and education, such as those by Stolte et al. (2020) and Pasarín-Lavín et al. (2023), have demonstrated a significant relationship between creativity and EF. More specifically, the first of those two studies suggested that updating, one component of EF, positively predicted mathematical creativity in primary school children, also showing statistically significant correlations with mathematical ability and general creativity. Similarly, the second study highlighted a clear relationship between flexibility and creativity, with a positive relationship between flexibility and Creativity and a negative relationship between inhibition and creative outcomes.

Neurodivergent students, such as those with ADHD, Dyslexia, ID, and Giftedness, are commonly associated with various challenges in the learning and cognitive process. In this regard, previous research suggests that they may show cognitive impairments in EF and Creativity (Axbey et al., 2023; Mareva et al., 2024). They may also experience deficits in cognitive abilities, creativity communication and language, behavior control, and autonomy (Ashman & Conway, 2017). These deficits can impact individuals in their everyday life, including psychologically, personally, socially and academically (Cristofori et al., 2019). It is commonly assumed that neurodiverse learners may have lower skills, although this perception may not be accurate. In fact, many of these students may have exceptional executive and creative skills that are not always recognized due to limitations in assessment processes or insufficient understanding of their learning profiles (Di Lieto etal., 2020; Danielsson et al., 2012; Renzulli & Reis, 2012). It is possible that current measures of creativity are designed for neurotypical brains and do not always provide the flexibility and appreciation needed to capture different creative strengths (Hayashibara et al., 2023). By understanding and supporting the development of these abilities in neurodiverse learners, educators can enhance students' ability

to learn effectively, solve problems independently and participate meaningfully in society (Benedek et al., 2014).

Creativity and Neurodivergent Learners

Creativity is often analyzed as a part of assessing Gifted students (Guignard et al., 2016; Renzulli & Reis, 2021), However, some studies suggest that that creativity and the specific needs of neurodiverse students may be interconnected (Govindasamy et al., 2023). Therefore, creating a creative educational environment could benefit these students by promoting socialization and adaptation (Ivanova & Doncheva, 2019).

Neurobiologically, creativity is associated with the interaction of various brain regions, including the prefrontal cortex, temporal lobes, and limbic system (Khalil et al., 2019; Shen et al., 2017). Studies exploring creativity in neurodivergent populations have illuminated both deficits and strengths across these conditions. For instance, individuals with ADHD, characterized by atypical functioning in the prefrontal cortex, may exhibit challenges in sustained attention and impulse control, yet paradoxically demonstrate heightened divergent thinking and novel problem-solving approaches indicative of creative potential (Hoogman et al., 2020; Takeuchi et al., 2020). Similarly, individuals with ID, such as children with Down Syndrome, may showcase similar fluency, flexibility, originality and elaboration to neurotypical students, but score lower in verbal production (De Caroli & Sagone, 2014). Conversely, individuals with Dyslexia may demonstrate unique patterns of creativity, drawing upon intense visualization skills (Šimčíková, 2018). Lastly, as one might expect, Gifted individuals, with their enhanced cognitive abilities and neural connectivity, may demonstrate exceptional creativity in a variety of domains (Renzulli & Reis, 2020).

Understanding the neural underpinnings of creativity in neurodivergent learners is important for psychoeducational assessments and educational practices aimed at assessing and developing creative expression (Long et al., 2022). This can ultimately foster a more inclusive learning environment that values diverse cognitive profiles and talents.

Executive Functions and Neurodivergence

Neurodivergent students often exhibit variations in executive functions, impacting their ability to organize information, plan tasks, and regulate impulses (Mareva et al., 2024). Understanding the specific brain zones affected in conditions like ADHD and ID provides insights into the cognitive processes that may pose challenges for these students (Stoodley, 2014).

Some authors argue that deficits in EF are the cause of core cognitive difficulties in some neurodiverse individuals, while others find only subtle difficulties in certain types of neurodiverse learners. Additionally, other authors have suggested that impairments in EF may be induced by the clinical or social problem itself (Di Lieto et al., 2020).

Recent studies (Fiske & Holmboe, 2019; Friedman & Robbins, 2022) have emphasized the neurobiological basis of these cognitive processes, with attention to brain regions such as the prefrontal cortex, basal ganglia, and parietal cortex. For instance, research into ADHD (Clark et al., 2007; Nejati et al., 2020) has emphasized dysregulation in the prefrontal cortex, contributing to deficits in EF such as working memory and inhibitory control.

Similarly, research on Dyslexia (Barbosa et al., 2019; Varvara et al., 2014) has demonstrated atypical activation patterns in brain regions involved in EF. This sheds light on the challenges faced by those with Dyslexia in attention and inhibition. However, studies have found that EF such as planning are not affected (Moura, et al., 2014).

ID involves limitations in intellectual functioning and adaptive behaviors. From a cognitive perspective, individuals with intellectual disabilities may face challenges in various EF, such as working memory, inhibition, and cognitive flexibility (Erostarbe-Pérez, et al. 2022). However, it is essential to recognize that in other executive functions, such as planning, no significant results have been found (Danielsson et al., 2012). In contrast, studies on Giftedness have highlighted enhanced EF, correlated with increased activation in brain regions associated with cognitive control and problem-solving (León, 2020).

These results also highlight the importance of tailored educational and psychological assessments and interventions that address the unique cognitive profiles of neurodivergent students, facilitating academic success and helping them achieve their cognitive potential (García et al., 2014).

The Present Study

Results from previous studies suggest that neurodiverse students exhibit a wide range of strengths and weaknesses in various cognitive, social, practical and creative components of learning. While they may experience difficulties in certain areas, they also have unique ability profiles that may manifest as strengths in other areas, such as EF and Creativity.

Creativity is a fundamental component of our society, driving innovation, problem solving, and cultural development (Tang, 2017). Despite its importance, creativity has often been undervalued in educational research, overshadowed by a focus on more traditional

cognitive domains. By prioritizing creativity in our research, we aim to highlight its crucial role in fostering holistic development and addressing the diverse needs of all people.

Additionally, the study focuses on EF, mainly working memory, planning, and flexibility, which are crucial for the learning process and are closely related to Creativity. Other EF, such as attention, were not the main focus of this study because they serve as underlying EF that support several cognitive processes, including those that are the objective of our current study (Clark et al., 2021; Miyake et al., 2000).

Analyzing these components from a neurodiverse perspective may demonstrate that measurement may be tailored for neurodivergent students. A neurodiverse perspective in assessing and intervening in EF and creativity can help all students demonstrate and strengthen their skills, promoting more effective and strength-based learning.

Bearing this in mind, the aim of the present study is to analyze differences in creativity (Verbal and Figural) and EF components (working memory, planning and flexibility) between five groups: neurotypical students, students with ADHD, students with Dyslexia, students with ID and Gifted students.

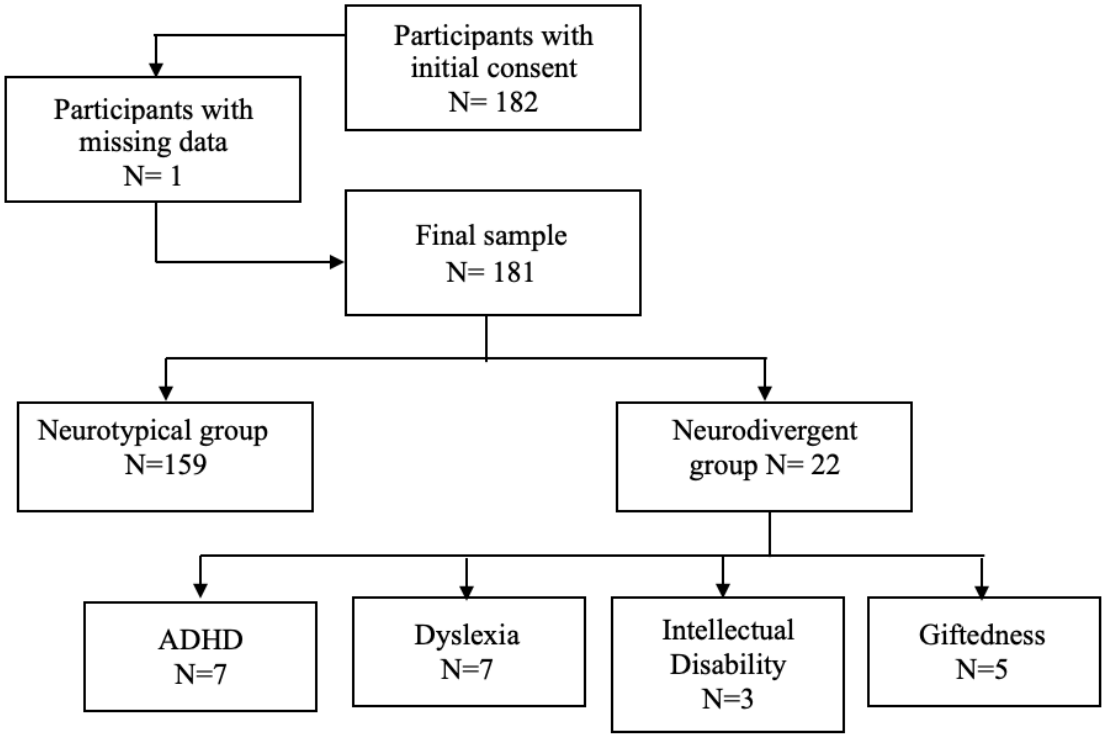
Materials and Methods

Participants

The initial sample consisted of 182 high school students. Due to missing data for one student, a total of 181 secondary school students from the North of Spain (M_{age}=13.33; SD_{age}=1.19; 93 boys, 88 girls) participated in the study. They were put into one of two groups: Neurotypical Students (N=159) and Neurodivergent students (N=22), depending on whether they had a formal diagnosis of SEN or not. The Neurodivergent student group was split into 4 groups by diagnosis: ADHD, Dyslexia, ID and Giftedness (Figure 1). In order to ensure the accuracy of the study, the data were collected from students with SEN who had been accurately identified by the educational guidance department and who had subsequently received appropriate educational reports and adaptations. The sample was obtained through convenience sampling procedures, since students were selected based on specific inclusion criteria, as outlined in the following section.

Figure 1.

Participant flow chart showing the progression of participants throughout the study



Note: ADHD = Attention Deficit Hyperactivity Disorder

Procedure and inclusion criteria

The study was carried out following the ethical principles for research involving human beings as stated in The Code of Ethics of the World Medical Association's Declaration of Helsinki (World Medical Association, 2013). The ethical committee of the Principality of Asturias (reference: CEISH-UPV/EHU, BOPV 32) granted approval for the study which was conducted in compliance with applicable laws and institutional policies. The research was presented to teachers, who were then asked to collaborate with the researchers in obtaining parental consent for their students' participation in the study.

The group of neurodivergent students was composed of children with a formal diagnosis (made by the psycho-pedagogical team at the school) specifying the type of SEN they had. In Spain, the diagnosis of SEN students is usually made through the use of several instruments. First, structured interviews conducted to teachers, families, and the student, based on the DSM-5 (American Psychiatric Association [APA], 2013). These interviews allow the professional to identify core cognitive, emotional and behavioral components of a disorder, but

also provide insights on significant comorbidities and potentially confounding factors, such as sensory impairments, school absenteeism, severe emotional problems, or disruptive behaviors, among others. Second, standardized tests of intelligence are used to confirm a student´s general IQ. Finally, specific components such as language, perception, attention, reading skills, and other relevant measures, are administered, depending on the suspected diagnosis. The process usually involves the following steps: (1) the student's academic performance is evaluated to determine if it is significantly lower than their intellectual ability; (2) an evaluation is conducted to identify any deficits in basic cognitive processes that could explain the gap between the student's ability and performance; (3) possible contributing factors, such as visual, auditory, motor, emotional, and other influences, are explored to understand the deficits identified; (4) curriculum access modifications are made to the conditions affecting the student's ability to engage with the standard curriculum. Most students continue with the regular curriculum, with necessary adaptations to enhance their learning and participation. They may also receive supplementary instruction tailored to their specific learning needs outside the regular classroom setting (Núñez et al., 2011).

The assessment of EF was conducted by a specialist psychologist, who is an expert in VR, in groups of five students due to the immersive nature of the virtual reality tool. Creativity was evaluated for each participant individually by four experts in educational psychology from the research group in northern Spain.

The following inclusion criteria were considered for this study: (1) students do not exhibit any other comorbid disorder; (2) they attend regular schools and are enrolled from 1st to 4th grade of secondary education; and (3) they demonstrate sufficient comprehension skills to perform the tasks of creativity and EF.

Comorbidity and the presence of other confounding factors were also considered in the present study. Following Núñez et al., (2022) different exclusion criteria were used: the presence of significant medical or severe emotional problems, comorbid disorders (e.g., developmental coordination disorder, present specific language impairment), sensory impairment, a history of chronic absenteeism, disruptive behaviors, or not having received appropriate instruction and/or intervention. This identification is important since these factors may further complicate a student learning experiences and require a multifaceted approach to intervention.

The prevalence rates of different types of neurodiversity found in the present study were within the ranges established by various authors (Table 1). For ADHD, the prevalence rate ranges from 3-7% (American Psychiatric Association [APA], 2013) to 5-8% (Rusca-Jordán & Cortez-Vergara, 2020), depending on the studies. For Dyslexia, different studies report prevalence between 4-9% (American Psychiatric Association [APA], 2013) and 3-7% (Wagner et al., 2020). For ID, the worldwide prevalence is 1% (American Psychiatric Association [APA], 2013; Harris, 2006). Finally, Giftedness affects 3-5% of the global population (Borland, 2010).

Table 1.

Demographic Characteristics of the Sample

Groups		**Gender**		**Age**	
	n	M	F	*M*	*SD*
Neurotypical	159	81	78	13.29	1.71
ADHD	7	4	3	13,57	1.27
Dyslexia	7	5	2	13.71	1.25
ID	3	0	3	15.00	1.00
Giftedness	5	3	2	12.80	1.09
Total	181	93	88	13.33	1.19

Instruments

PIC -J. Prueba de Imaginación Creativa para Jóvenes - Creative Imagination Test for Young People

PIC-J. (Artola, T., et al. 2008) was developed to evaluate the creative capabilities of adolescents aged 12 to 18. The tool consists of four games, and this study primarily focused on games 2 and 4.

Game 2 (Verbal Creativity) is an adapted version of the Alternate Uses Test of Guilford (AUT; Guilford, 1967) which uses a rubber tube as a stimulus object. It evaluates the capacity for innovative problem-solving and outside-the-box thinking through measuring verbal fluency, flexibility, and originality by exploring different applications of a given object. Fluency refers to the ability to generate a large number of ideas or solutions within a given time frame. Flexibility involves the capacity to approach problems from different angles and switch between various strategies. Originality relates to the uniqueness and novelty of the ideas generated, emphasizing creativity's ability to produce unconventional and imaginative solutions (Guilford, 1967). The instructions are as follows: "*Make a list of all the things a rubber tube can be used for. Think of interesting and original things. Write down all the uses*

you can think of, even if they are imaginary. You can use any number and size of tubes. For example: As a water pipe".

Game 4 (Figural Creativity) is geared towards assessing participants' ability to produce innovative responses by instructing them to sketch something that is beyond conventional imagination. This task serves as a graphic imagination assessment influenced by the Torrance Test of Creative Thinking (TTCT; Torrance, 1998). The instructions for the game are as follows "*On this page you can see some incomplete drawings. Try to complete them by drawing an original picture that nobody else would have thought of. Then give each drawing an interesting title*".

The reliability of the test, as reported by its authors, is high, with a Cronbach's Alpha coefficient of .85. Table 2 shows the maximum and minimum values for each creativity variable in the sample used for the study.

The following variables from the test were included for analysis: from Game 2, raw scores of verbal fluency, verbal flexibility and verbal originality; from Game 4, raw scores of figural originality, figural elaboration, figural title and figural details.

PIC-J Interrater agreement. One of the primary challenges in assessing creativity is obtaining comparable ratings from multiple evaluators. To address this, interrater agreement was implemented to validate the effectiveness of the PIC-J scoring. Cohen's weighted kappa statistic (*k*) was used to calculate the level of agreement, which is a widely used measure of interrater reliability. The methodology outlined by Landis and Koch (1977) can be used to interpret coefficient *k*. A score below 0.00 indicates poor agreement; 0.00-0.20 slight; 0.21-0.40 fair; 0.41-0.60 moderate; 0.61-0.80 substantial; and 0.81-1.00 almost perfect agreement.

To apply the Cohen's Kappa, two raters analyzed at least 25% of the sample, following the same instructions and criteria for rating the independent variables.

In the initial agreement, the *k* value was slight for several measures, with notable values in Verbal Fluency (substantial, >0.61), Verbal Flexibility (moderate, > 0.41) and Graphic Details (moderate, >0.41). Twenty additional participants were assessed after inter-rater agreement was achieved and a *k* value indicating almost perfect agreement was obtained for Verbal Fluency and Figural Elaboration (>0.81), and substantial agreement for Verbal Flexibility, Verbal Originality, Figural Originality, Figural Title and Graphic Detail (>0.61).

Nesplora Executive Functions – Ice Cream

Nesplora Executive Functions - Ice Cream is an innovative evaluation tool that assesses various aspects of EF in individuals aged 8 and over. It provides a virtual reality experience that immerses the participant in a realistic, multitasking setting, emulating the first day at an ice cream shop. During this virtual quest, lasting between 20 and 45 minutes, the participants must manage a series of rules and objectives that reflect the obstacles of daily life.

As Fernández et al. (2023) explain, the student receives the stimuli through VR equipment with glasses, motion sensors and headphones that allow them to see and hear what is happening in the virtual ice-cream-shop environment. All instructions are received via audio. The test begins by placing the individual in the role of the ice-cream server at the counter, listening to the instructions for what they have to do from the shop's cashier. To do the tasks, the ice-cream server is given objects with various functions: an ice-cream maker, a waste bin, a recipe book, a telephone and a clock.

After a usability test, the task begins with the message: "You'll be working at the ice cream shop for a while. Customers come in groups of four and you must serve them following your boss's orders. Call your boss and he'll tell you his priorities for serving customers. Click on the phone to call him". The boss explains the instructions, the learner takes a test to check the instructions, the shifts, and the recipes, and begins the task.

The test records every click, every reaction time and every click between customer avatars, ice-cream machine buttons or other incorrect objects. The test measures learning, planning, attention, working memory, cognitive flexibility and processing speed. Global indices of planning, working memory and cognitive flexibility are provided at the end. Its reliability is notable, with all of the important variables exhibiting a McDonald's Omega coefficient between .85 to .97 (Fernández et al. 2023). Table 2 shows maximum and minimum values of the variables in the sample used for the present study.

The test provides raw scores for Planning, Working Memory and Cognitive Flexibility. Two indicators are provided for Cognitive Flexibility: Interference and Perseveration. Interference refers to the disruption caused by irrelevant or conflicting information that interferes with an individual's ability to switch between tasks, mental sets, or strategies; while Perseveration is involuntary or persistent repetitions of the same thought, response, or action, even when they are no longer relevant or appropriate to the current task. Higher scores in these variables are indicative of difficulties in flexibility or shifting. On the other hand, higher scores

in Planning and Working Memory are associated with higher performance in these specific cognitive skills.

Wechsler Intelligence Scale for Children (WISC-V)

The study used the Spanish version of the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V; Wechsler, 2014). The internal consistency of the Spanish adaptation of the WISC-V was assessed using the two-half method, indicating a high reliability coefficient of 0.95 for Full Scale IQ (FSIQ) (Amador & Forns, 2019). The FSIQ was derived from seven primary subtests: Similarities and Vocabulary for Verbal Comprehension, Block Design for Visual Spatial abilities, Matrix Reasoning and Weights for Fluid Reasoning, Digit Span for Working Memory, and Symbol Search for Processing Speed. The FSIQ score was used as a covariate for statistical comparison between groups.

Data analysis

Statistical analyses were conducted using SPSS 27.0.

First, descriptive analyses of the study variables for both Creativity and EF were performed (Table 1) and indicators of normality (kurtosis and skewness) were verified for the sample. Subsequently, parametric analysis was performed using Multivariate Analysis of Covariance (MANCOVA) to determine the multivariate effect of differences between neurodiverse groups considering age and IQ as covariates. The score ranges differed between variables (Table 2), some of which included negative values. Thus, each variable had its own distribution. It is important to note at this point that groups were compared on a particular skill (i.e., Verbal Fluency, Verbal Flexibility, Verbal Originality, Figural Originality, Figural Title, Figural Details, Planning, Working Memory, Flexibility-Interference, and Flexibility-Perseveration) rather than each group being compared across the different variables. Differences were considered statistically significant at a level of $p \leq .05$. *Sheffé* multiple comparisons were used to identify the differences between the groups. Effect sizes were calculated using *partial eta squared* (*ηp2*) following *Cohen's d* criteria (1988), which established the following levels: d<.20 indicates a minimal effect size; d between 0.20 and 0.50 (ηp2=0.01) indicates a small effect size; d between 0.50 and 0.80 (ηp2= 0.059) a medium effect size; and d> 0.80 (ηp2= 0.080) a large effect size.

Results

Initial analysis

Based on the findings from Finney and DiStefano (2006), the values for skewness and kurtosis suggested a normal distribution for all data points, except for Flexibility-Perseveration, which had slightly higher kurtosis, with maximum acceptable values in each case for this type of analysis being ±7, as shown in Table 2.

Table 2.

Descriptive Statistics for the Studied Variables

Variables	Min	Max	*M(SD)*	*Kurtosis*	*Skewness*
Verbal Fluency	1	29	9.06(5.21)	1.02	.983
Verbal Flexibility	1	17	6.47(3.08)	-.052	.396
Verbal Originality	0	29	7.53(5.76)	1.00	1.14
Figural Originality	0	11	4.71(2.40)	-.418	.221
Figural Elaboration	0	7	.837(1.23)	4.83	1.93
Figural Title	0	7	1.59(1.81)	.244	1.04
Figural Details	0	4	.458(.759)	3.43	1.84
Planning	1	14	10.11(3.92)	-.645	-.839
Working Memory	20	56	46.47(7.26)	.797	-.992
Flexibility-Interference	-29	100	14.68(19.74)	4.53	1.74
Flexibility-Perseveration	0	13	1.43(2.09)	7.67	2.48

Note. Min = Minimum; Max = Maximum; M = Mean; SD = Standard Deviation

The descriptive statistics for the variables indicated wide variability in the scores, as shown by the standard deviations. For example, for Verbal Fluency, the standard deviation was greater than 5, indicating considerable dispersion in the scores around the mean. Similarly, the standard deviation for Flexibility-Interference was remarkably high, over 19, suggesting large variability in participants' scores. In addition, it is worth noting that some variables ranged from negative values to a maximum of 100, as was the case for Flexibility-Interference. This is due to the nature of the measure, where a negative value indicates higher performance on the task, while a higher value indicates poor performance.

Verbal Creativity in Neurodivergent Students

First, a MANCOVA analysis was conducted, with IQ and age as covariates. The multivariate tests showed statistically significant differences between groups in IQ (p=.014;

ηp2=.06) and nearly significant differences in age (*p*=.050; *ηp2*=.044). Table 3 shows the means and standard deviations of the five groups in the Creativity variables.

There were differences in the groups' mean scores for the Verbal Creativity variables (Table 3). In Verbal Fluency, the Gifted group had the highest mean score, closely followed by students with ADHD, both higher than the Neurotypical group. The ID group had the lowest scores. There were similar results in Verbal Flexibility. The highest mean score in Verbal Originality was from students with ADHD, closely followed by the Gifted group, while those with ID had the lowest mean score.

In this regard, the MANCOVA analysis indicated statistically significant differences for Verbal Creativity (λ=.86; *F(12,455*)=2.222; *p*=.010; *ηp2*=.049), although the effect size was small, suggesting that the impact of the independent variable(s) on verbal creativity may not be particularly large in practical terms. Inter-subject effects indicated that these differences were found for the Verbal Originality variable (*F(4,488*)=4.125*; p*=.003; *ηp2*=.087), with a large effect size in this case.

Subsequently, a deeper analysis of the verbal creativity variables, considering the groups using *Scheffé* post-hoc analysis, showed that there were statistically significant differences in Verbal Originality between students with ADHD and Neurotypical students (*p* = .022) and between the ADHD and ID groups in Verbal Originality (*p*=.010). The highest scores were from students with ADHD and the lowest from students with ID.

Table 3.
Descriptive Statistics of Verbal Creativity in the Different Groups

Variables	**Groups**				
	Neurotypical (n=159)	ADHD (n=7)	Dyslexia (n=7)	ID (n=3)	Giftedness (n=5)
Verbal Fluency					
M(SD)	8.89(4.93)	10.71(6.60)	11.00(8.60)	4.00(1.00)	12.40(6.47)
Verbal Flexibility					
M(SD)	6.37(2.85)	7.71(4.42)	6.86(5.49)	3.33(1.53)	9.20(3.11)
Verbal Originality					
M(SD)	7.17(5.14)	13.86(8.61)	9.71(11.22)	1.00(1.00)	11.00(4.36)

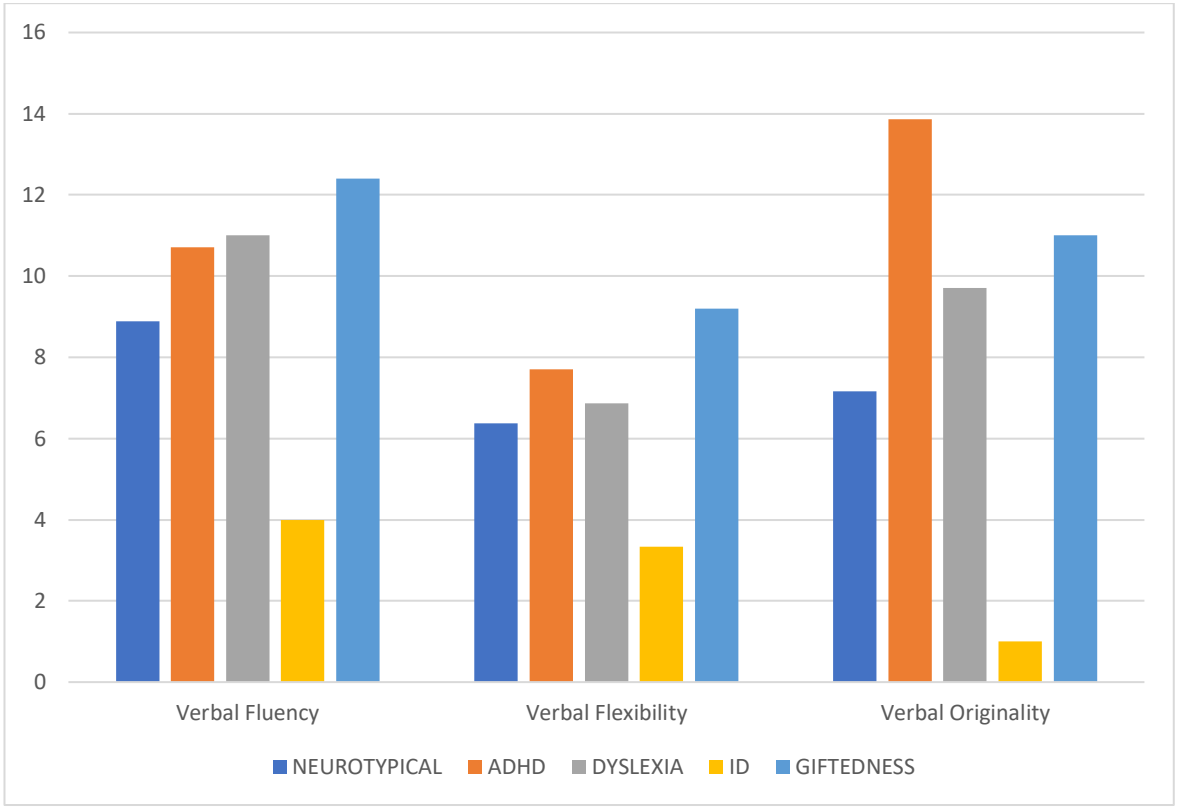
Note. ADHD = Attention Deficit Hyperactivity Disorder; ID = Intellectual Disability; M = Mean; SD = Standard Deviation.

Figure 2 shows the mean scores for the Verbal Creativity variables in the five groups: Neurotypical, Gifted, ID, ADHD and Dyslexia. It suggests variability in the mean scores

between groups, indicating potential differences in levels of Verbal Creativity in students with ADHD, Dyslexia and ID compared to the control group. The results show that the ID group scored lower than the others on most variables, with the originality variable being the lowest. On the other hand, the Gifted group consistently scored higher than the other groups in all variables except Originality, where the scores of students with ADHD stand out. In addition, the students with ADHD scored quite well on all variables compared to the other groups.

Figure 2.

Verbal Creativity in the Neurotypical Group and Different Neurodivergent Groups



Note. ADHD = Attention Deficit Hyperactivity Disorder; ID = Intellectual Disability

Figural Creativity in Neurodivergent Students

First, a MANCOVA analysis was performed using IQ and age as covariates. While there were statistically significant differences due to IQ (p=.041; $\eta p2$=.056), no statistically significant differences were found for age (p=.476; $\eta p2$=.020). For IQ, the effect size was medium, suggesting that the impact of the covariates may not be particularly large in practical

terms. Means and standard deviations for the components of Figural Creativity are shown in Table 4.

In Figural Originality, the Neurotypical group had the highest mean score, closely followed by the Dyslexia and Gifted groups. The ADHD group had the lowest mean score. The highest mean score in Figural Elaboration was from the Gifted group, followed by the Neurotypical group, while the ID group had the lowest mean score. In the Figural Title variable, the highest scores were from the Gifted and Neurotypical groups, while students with ADHD had the lowest. Finally, in Figural Details, the Gifted group again had the highest score along with students with Dyslexia (although with a considerable gap), and students with ADHD again had the lowest mean.

Despite these results, there were no statistically significant differences for these variables between the groups (λ=.92; $F(16,523)$=.890; p=.581; $\eta p2$=.020).

Table 4.
Descriptive Statistics of Figural Creativity in the Different Groups

Variables	**Groups**				
	Neurotypical (n=159)	ADHD (n=7)	Dyslexia (n=7)	ID (n=3)	Giftedness (n=5)
Figural Originality					
M(SD)	4.78(2.41)	3.29(2.81)	4.71(2.40)	4.33(3.06)	4.60(1.14)
Figural Elaboration					
M(SD)	.88(1.27)	.14(.378)	.69(.945)	.00(.000)	1.00(1.00)
Figural Title					
M(SD)	1.67(1.80)	.00(.000)	.51(.882)	.67(1.16)	3.20(2.39)
Figural Details					
M(SD)	.44(.731)	.29(.488)	.51(.882)	.33(.577)	1.20(1.64)

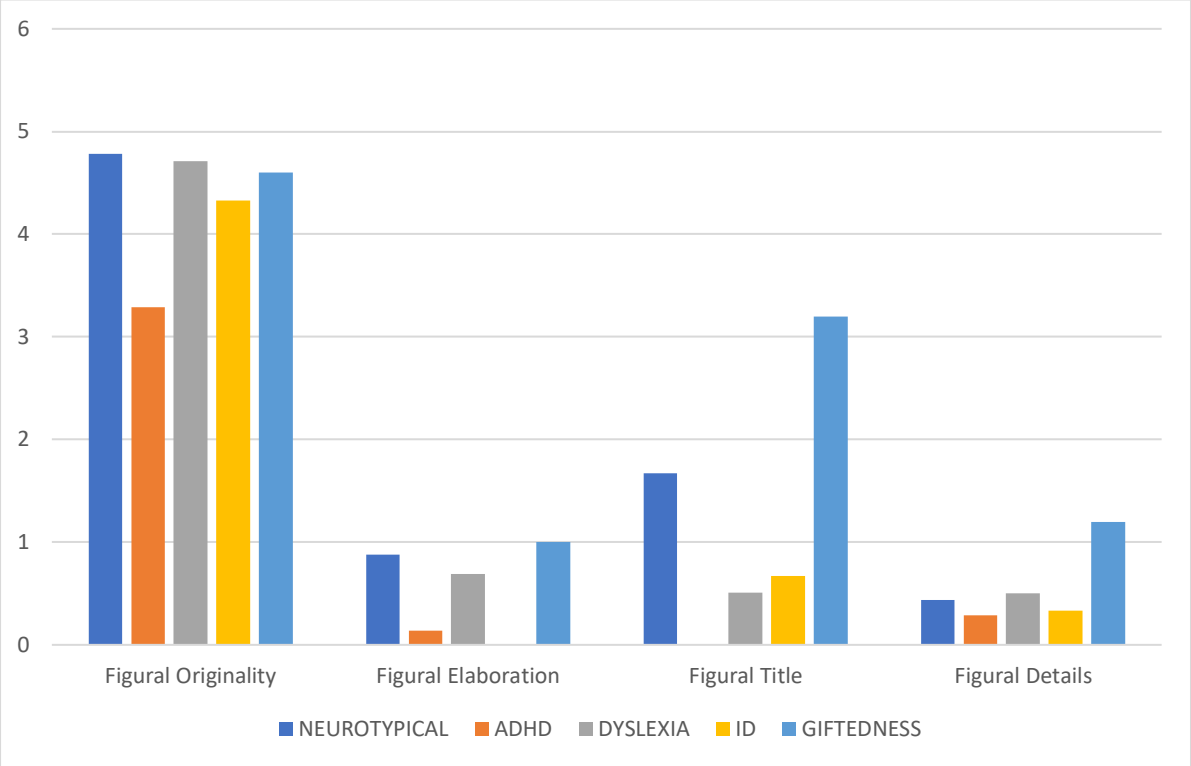
Note. ADHD = Attention Deficit Hyperactivity Disorder; ID = Intellectual Disability; M = Mean; SD = Standard Deviation.

Figure 3 shows the mean scores of the figural creativity variables in the different groups: Neurotypical, Gifted, ID, ADHD and Dyslexia. In particular, the Gifted group had significantly higher mean scores than the other groups. As the figure shows, students with ID had the lowest scores in all variables, except Figural Title. They had very low scores in variables such as Elaboration, which is not visible in the graph. Furthermore, students with Dyslexia had high scores in all variables except for Figural Title, while students with ADHD—

in contrast to Verbal Creativity—had the lowest scores in Figural Originality and Figural Details.

Figure 3.

Figural Creativity in the Neurotypical Group and Different Neurodivergent Groups



Note. ADHD = Attention Deficit Hyperactivity Disorder; ID = Intellectual Disability

Executive Functions in Neurodivergent Students

First, a MANCOVA analysis was performed using IQ and age as covariates, including group as the independent variable and the variables related to EF as dependent variables. Statistically significant differences were found in IQ (p=.005; $\eta p2$=.083) and age (p=.012; $\eta p2$=.073). The effect size using IQ as a covariate was large, indicating that differences in IQ scores between groups had a significant impact on the dependent variables. The effect size for age was medium, indicating that the impact of the covariates may not be particularly large in practical terms.

Table 5 shows the mean scores and standard deviations for the five groups in EF measures. In Planning, the ID group had the lowest scores, while the other groups exhibited similar performance. In Working Memory, the Gifted group had a substantially higher mean score than the other groups, followed by the Neurotypical group. Again, the ID students had

the worst performance. In particular, between-group differences were especially evident in Flexibility (Interference and Perseveration), where students with ID had the highest mean score (and worst performance), in contrast to the markedly lower mean score (better performance) in the Gifted group. The Neurotypical group also demonstrated good performance in these variables (lower scores) than students with ADHD or Dyslexia.

Table 5.

Descriptive Statistics of Executive Functions in the Different Groups

Variables	**Groups**				
	Neurotypical (n=159)	ADHD (n=7)	Dyslexia (n=7)	ID (n=3)	Giftedness (n=5)
Planning					
M(SD)	10.14(3.82)	10.45(3.69)	10.71(4.64)	5.00(6.93)	10.60(3.97)
Working Memory					
M(SD)	46.83(6.83)	44.21(7.71)	43.14(5.37)	28.33(9.07)	54.00(2.12)
Flexibility-Interference					
M(SD)	14.06(19.35)	22.10(35.03)	18.86(8.49)	36.33(17.21)	5.40(6.95)
Flexibility-Perseveration					
M(SD)	1.25(1.79)	2.63(4.62)	2.71(1.49)	6.67(3.51)	.400(.548)

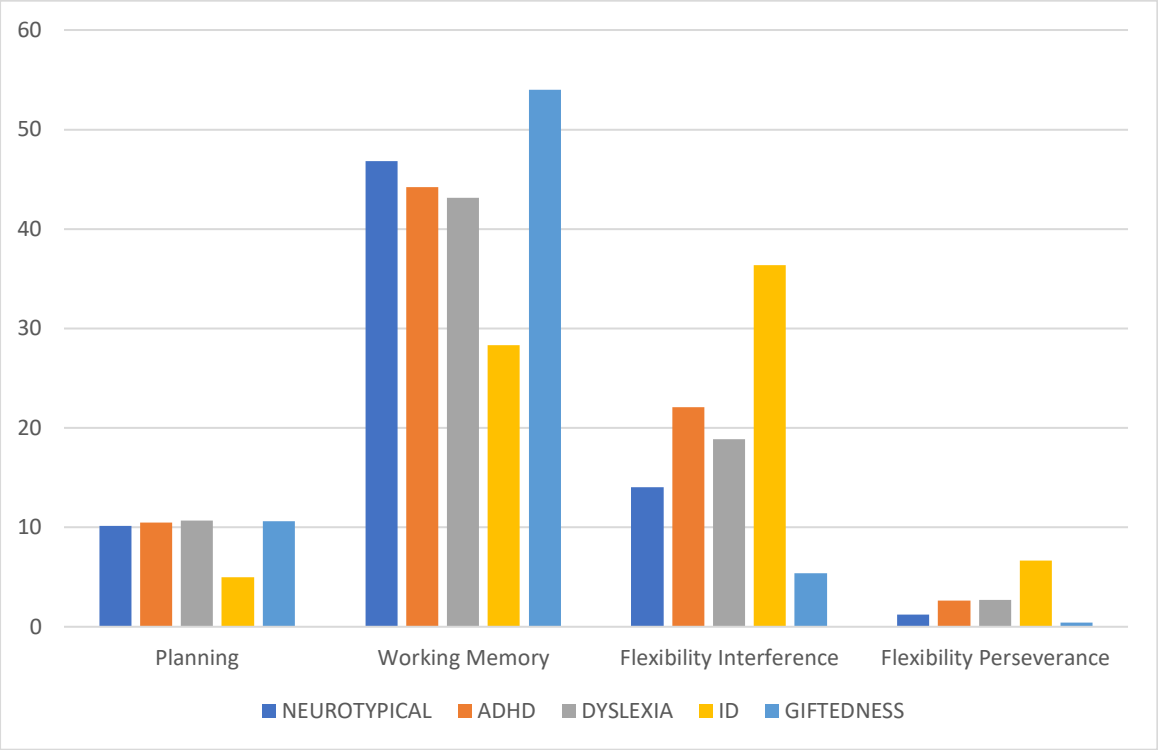
Note. ADHD = Attention Deficit Hyperactivity Disorder; ID = Intellectual Disability; M = Mean; SD = Standard Deviation.

MANCOVA analysis showed statistically significant differences for EF (λ=.83; $F(16,523)$=2.086; p=.008; $\eta p2$=.046). Inter-subject effects indicated statistically significant differences among groups in Working Memory ($F(4,223)$=5.179; p<.001; $\eta p2$=.106) and Flexibility-Perseveration ($F(4,20)$=5.294; p<.001; $\eta p2$=.109). Although there were statistically significant differences, the small effect sizes indicate minimal impact of the different groups on EF in practical terms.

Subsequently, a deeper analysis of EF differences, using *Scheffé's* post-hoc analysis, showed that there were statistically significant differences between the ID group and all other groups in Working Memory: Neurotypical (p < .001), ADHD (p = .008), Dyslexia (p = .018) and Gifted (p < .001); and between ID and the other groups in Flexibility-Perseveration: Neurotypical (p < .001), ADHD (p = .033), Dyslexia (p = .040) and Gifted (p < .001).

The mean scores in the EF variables are shown in Figure 4.

Figure 4.
Executive Functions in the Neurotypical Group and Different Neurodivergent Groups



Note. ADHD = Attention Deficit Hyperactivity Disorder; ID = Intellectual Disability

Discussion

The present study aimed to examine differences in Creativity (both Verbal and Figural) and components of EF (including Working Memory, Planning, and Flexibility) between five distinct groups: Neurotypical Students, students with ADHD, students with Dyslexia, students with ID, and Gifted students. By exploring these cognitive domains through a neurodiverse lens, this research seeks to shed light on the unique challenges of diverse learners and inform the development of more adaptive, equitable educational practices, fostering more inclusive and supportive learning environments for all.

Differences in Creativity Among Neurodiverse Students

Creativity in neurodiverse students is a multifaceted issue that deserves attention because of its implications for learning and cognitive development. Results from the present study show significant differences in verbal creativity across different neurodivergent conditions, including ADHD, Dyslexia, ID and Giftedness.

The study showed different results between the groups in general, but more specifically, it highlighted the advantage of students in the ADHD group in Verbal Originality, who performed better than Neurotypical and Gifted Students. They also performed slightly better

than the Neurotypical group in Verbal Flexibility and Verbal Fluency. These results are consistent with previous studies, such as Hoogman et al. (2020), suggesting a potential area of strength within this neurodivergent population. More specifically, the advantage of the ADHD group could be explained by the fact that these children may exhibit higher performance in divergent tasks due to their lower cognitive inhibition, which may allow them to explore a wider variety of options and solutions in divergent assessment tasks (Hoogman et al., 2020; Radel et al., 2015).

However, it is important to note that students with ID had the lowest scores in Verbal Creativity variables, consistent with De Caroli and Sagone (2014), highlighting the diverse cognitive profiles within the neurodivergent spectrum. Gifted students had the highest scores in Verbal Fluency and Flexibility as well as good scores for Verbal Originality. Previous studies, such as Renzulli and Reis (2020), support this finding as well as highlighting the importance of considering Creativity as an important variable for diagnosing Giftedness, together with high levels of intrinsic motivation.

The low performance of the ID group, however, may be due to the assessment tasks and a lack of adaptation to their level of understanding or cognitive ability. Several authors have noted the importance of adapting assessments to ensure that they are accessible and equitable for all students, including those with ID (Kooijmans et al., 2022; Namara & Hollinger, 2003).

Figural creativity, on the other hand, represents another dimension of cognitive expression in neurodivergent learners. Despite of the lack of statistically significant differences at a general level, the mean scores for this component showed trends that are worth noting. For example, individuals with ADHD had the lowest scores in elements of Figural Creativity such as Figural Title and Figural Details. They also scored poorly in Figural Elaboration, only outperforming the ID group. This is consistent with the study by González-Carpio et al. (2017). It is worth noting that this is in contrast to the high scores from the ADHD group in Verbal Creativity, which could be explained by the fact that people with ADHD frequently exhibit deficits in paying attention to details and maintaining concentration in tasks that require spatial processing.

On the other hand, students with Dyslexia demonstrated high Figural Originality, reaching the same level as Neurotypical students, nor did they have low scores for Figural Elaboration and Details. These results are consistent with studies such as Lam and Tong (2021), who claimed that children with Dyslexia may show good Figural Creativity.

In a similar vein, and also according to Renzulli and Reis (2020), Gifted individuals showed consistently higher mean scores in the figural creativity variables, suggesting enhanced creative abilities in this subgroup.

Executive Functions in Neurodiverse Learners

EF play a key role in shaping cognitive processes and academic outcomes in neurodiverse learners, reflecting differences between neurodivergent conditions (Di Lieto et al., 2020). Results from the present study showed statistically significant differences in EF between the different groups, particularly in Flexibility-Perseveration. In particular, students with ID showed different patterns of executive functioning, with higher scores on Flexibility-Interference and -Perseveration—meaning worse performance. This is consistent with Erostarbe-Pérez et al. (2022) and might be explained by the fact that people with ID may show more Perseveration and Interference due to difficulties in inhibitory control, cognitive flexibility, information processing and self-regulation, among other factors associated with their condition (Danielsson et al., 2012). In addition, as mentioned above, assessment tasks may not be adapted to the level of understanding or cognitive capacity of some students within this group (Kooijmans et al., 2022).

Another interesting finding along the same lines is that students with ADHD performed similarly to Neurotypical students in Working Memory in contrast to the results reported by Clark et al. (2007) and Nejati et al. (2020), who claimed that dysregulation of the prefrontal cortex contributes to Working Memory deficits. The ADHD group scored similarly to the Neurotypical group in Planning, which is consistent with studies such as Boyer et al. (2014), who claimed that only a small proportion of students with ADHD show deficits in this executive function. Instead, these students demonstrated high Flexibility-Interference and Perseveration, which may be related to inattention, inhibition and flexibility, as noted in studies such as Pazvantoğlu et al., (2012).

In contrast, the Gifted students had significantly higher mean scores in Working Memory, highlighting their enhanced cognitive abilities in this domain (León, 2020).

Finally, these results showed no deficits or strengths in terms of EF for students with Dyslexia, who performed similarly to the Neurotypical group, with the exception of Working Memory. Although this difference was not statistically significant, it is somewhat in line with studies such as Barbosa et al. (2019), who claimed that students with Dyslexia show deficits in Working Memory but not in Planning.

On the whole, the findings from the present study highlight the importance of tailored educational approaches that recognize and harness neurodivergent students' creative and

cognitive potential while addressing their unique cognitive profiles and challenges, and suggest the need for tailored interventions that address unique profiles. As our results suggest, most students with SEN can demonstrate specific areas of strength and weakness in terms of Figural and Verbal Creativity, and EF.

Limitations and Future Directions

Although this study provides valuable information on the relationship between Creativity, EF and neurodiversity in students, there are also some limitations to be considered. First, the sample size for the study was relatively small, which may limit the generalizability of the findings. While the study included several groups representing common neurodivergent conditions found in clinical and educational settings, a larger and more diverse sample would improve the robustness and applicability of the findings, although the distribution of neurodiverse groups were consistent with the percentages of SEN in the population, as noted in the participants section.

In addition, using VR to assess EF, while novel and ecologically valid, may not have captured the full complexity of these constructs, as many of the tests used have not been tested on very large population samples (Pieri et al., 2023). In addition, VR environments can simulate certain aspects of the real world, they may not fully replicate the wide range of cognitive demands and contexts found in everyday life (Schöne et al., 2023). In addition, assessments of EF and Creativity are usually designed for neurotypical students. Future research could use a broader range of assessment tools and methods to provide a more complete understanding of these constructs in neurodiverse populations.

Furthermore, although this study examined Creativity and EF in neurodivergent groups, it did not explore possible underlying mechanisms or causal relationships. More focused studies on these causes could provide a more comprehensive perspective on these variables.

Despite these limitations, this study has important implications for both research and practice. By highlighting the unique cognitive profiles and strengths of neurodivergent learners, it underlines the importance of adopting a strengths-based approach in educational and clinical settings. Special consideration should be given to the ID group in this case, who demonstrated the greatest difficulties in most cases, which may be due to the standardized tests not being adapted to their level of comprehension, as they are designed for neurotypical learners. To this end, there is a need to develop and validate specific assessment instruments for students with ID, taking into account their characteristics and needs, and investigate the effectiveness of different assessment strategies for this population.

In the future, assessments and interventions should be tailored to specific needs and strengths. Learners are not able to demonstrate what they know because assessment and intervention tools are not adapted. A neurodivergent learner showing advantages in Creativity and/or EF could learn in a more adapted, efficient way if these components were properly examined and trained, as they can act as important bridges for building new knowledge. The creation of ecological, adaptive, accessible tools for assessing and training EF and Creativity should therefore be an important goal for researchers and educators.

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Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

Data will be made available on request.

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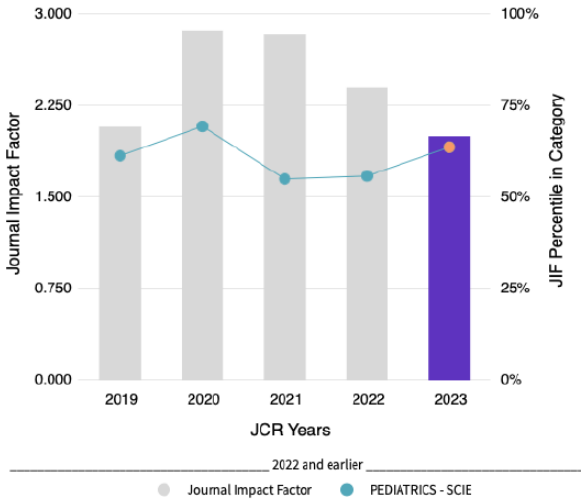
4.2. INFORME DEL FACTOR DE IMPACTO DE LAS PUBLICACIONES

En este apartado se presenta un informe sobre el Factor de Impacto de las revistas donde se han publicado los artículos mencionados. Los tres estudios están publicados en revistas indexadas en la JCR Social Science Edition. La información proporcionada ha sido obtenida del portal Journal Citation Reports de la Web of Science, e incluye tanto el Factor de Impacto como el ranking por disciplina, además de otros datos relevantes.

Children. Esta revista tiene un Factor de Impacto = 2.4 en el año 2023. En la categoría de "Pediatrics" se ha situado en el puesto 58 de 130 revistas incluidas en esta categoría, lo que la sitúa en el segundo cuartil (Q2).

2.0

2023 Journal Impact Factor



CATEGORY

PEDIATRICS

68/186

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2023	68/186	Q2	63.7

Rank by JIF before 2023 for PEDIATRICS

EDITION

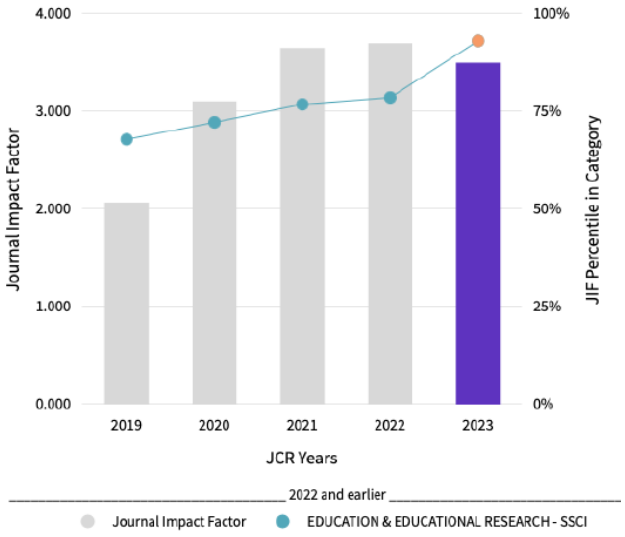
Science Citation Index Expanded (SCIE)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	58/130	Q2	55.8
2021	59/130	Q2	55.00
2020	40/129	Q2	69.38
2019	50/128	Q2	61.33

Thinking Skills and Creativity. Esta revista tiene un Factor de Impacto = 3.5 en el año 2023. En la categoría "Education & Educational Research" se ha situado en el puesto 53 de 756 revistas incluidas en esta categoría, lo que la sitúa en el cuartil 1 (Q1).

3.5

2023 Journal Impact Factor



CATEGORY

EDUCATION & EDUCATIONAL RESEARCH

53/756

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2023	53/756	Q1	93.1

Rank by JIF before 2023 for EDUCATION & EDUCATIONAL RESEARCH

EDITION

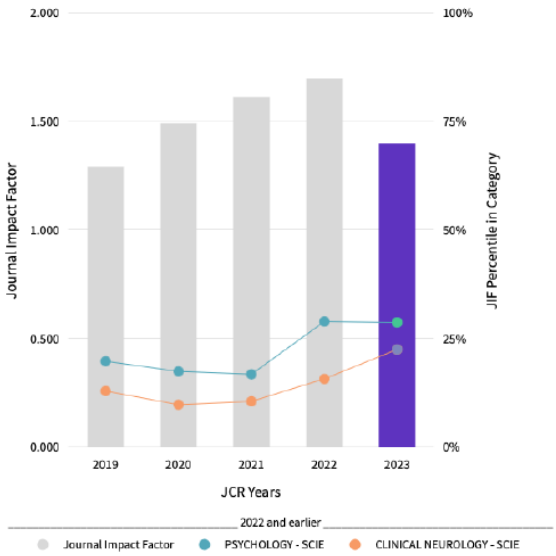
Social Sciences Citation Index (SSCI)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	58/269	Q1	78.6
2021	63/270	Q1	76.85
2020	74/265	Q2	72.26
2019	85/263	Q2	67.87

Applied Neuropsychology – Child. Esta revista tiene un Factor de Impacto = 1.4 en el año 2023. En la categoría "Psychology" se ha situado en el puesto 66 de 92 revistas incluidas en esta categoría, lo que la sitúa en el cuartil 3 (Q3). En la categoría "Clinical Neurology" se sitúa en el puesto 215 de 277 revistas incluidas en esta categoría, lo que la sitúa en el cuartil 4 (Q4).

1.4

2023 Journal Impact Factor



CATEGORY

CLINICAL NEUROLOGY

215/277

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2023	215/277	Q4	22.6

Rank by JIF before 2023 for CLINICAL NEUROLOGY

EDITION

Science Citation Index Expanded (SCIE)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	179/212	Q4	15.8
2021	190/212	Q4	10.61
2020	188/208	Q4	9.86
2019	178/204	Q4	12.99

CATEGORY

PSYCHOLOGY

66/92

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2023	66/92	Q3	28.8

Rank by JIF before 2023 for PSYCHOLOGY

EDITION

Science Citation Index Expanded (SCIE)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	58/81	Q3	29.0
2021	67/80	Q4	16.88
2020	64/77	Q4	17.53
2019	63/78	Q4	19.87

4.3. ESTUDIO COMPLEMENTARIO 1.

En la presente Tesis Doctoral se incluye un trabajo complementario que se encuentra actualmente en proceso de revisión en la revista *Developmental Neuropsychology*.

Pasarín-Lavín, T., García, T., Rodríguez, C., & Núñez, J.C. (under review). Latent Profile Analysis of Creativity: Relations with Intelligence and Executive Functions. Developmental Neuropsychology.

ESTUDIO COMPLEMENTARIO 1:

Latent Profile Analysis of Creativity: Relations with Intelligence and Executive Functions.

Latent Profile Analysis of Creativity: Relations with Intelligence and Executive Functions.

Autores

Tania Pasarín-Lavín, Trinidad García, Celestino Rodríguez, José Carlos Núñez

Año de publicación | **Revista**

2024 | Developmental Neuropsychology

Palabras clave

Creativity, Executive functions, intelligence, LPA

Factor de impacto

JCR 2023 1.5 (Cuartil 3); posición 59/92, categoría “Psychology”

Abstract

Creativity is a crucial aspect of both educational and social development. Nevertheless, considerable variability is observed in students' creative abilities. The analysis of other constructs, such as executive functions (EF) or intelligence, may provide insight into these individual differences. For this reason, this study employs latent profile analysis to elucidate the extent to which these variables can explain these differences. A total of 182 students (M_{age}=13.34; SD=1.19) were analysed to identify different creativity profiles creativity in relation to intelligence, EF, gender, and special educational needs (SEN). The following instruments were employed: PIC-J, Nesplora Executive Functions - Ice Cream and WISC-V. Three profiles were identified with medium figural creativity but differing levels of verbal creativity. These profile were designated as low verbal creativity, medium verbal creativity and high verbal creativity. Furthermore, these profiles were aanalyzed with outcome variables given findings such as: (1) students with SEN exhibited higher verbal creativity in certain profiles; (2) Intelligence showed a strong correlation with most of creativity variables, except Figural Originalitiy; (3) EF such as planning and working memory also correlated with specific creativity variables. The findings suggest the need for tailored educational interventions based on individual creativity profiles, especially for students with SEN.

Keywords: *Creativity, Executive functions, intelligence, LPA,*

Introduction

Understanding the multifaceted nature of creativity and its implications for various outcome variables is essential for advancing our knowledge of cognitive processes and behavioral outcomes. Creativity is a very important construct in today's society and more specifically in the field of education (Runco & Acar, 2012). It is defined as the capacity to generate new ideas or establish new associations among existing ideas to adjust responses to different circumstances and develop innovative solutions (Guilford, 1967; Sternberg, 2020). This construct is rooted in a blend of originality and practical usefulness (Runco & Jagger, 2012) and is considered one of the skills to be developed in education in order to improve academic performance and create citizens who will have the skills described in The Future of Jobs Report (World Economic Forum, 2023).

Fostering creativity enhances students' abilities by promoting problem solving and developing adaptive skills (Ritter et al., 2020). However, it is very difficult to define as there is a great deal of heterogeneity in the types of creativity, how it is measured and the creative profiles of individuals (Barbot, 2019; Dow, 2022). From a psychological and educational point of view, it is important to provide more information on how cognitive processes, such as Executive Functions (EF), may influence creativity, as some studies have found relationships between creativity and intelligence, and creativity and EF. However, this previous research has only focused on how creativity, as a direct and general measure, affects intelligence (Guignard et al., 2016; Ilagan & Patungan, 2018) or EF (Pasarín-Lavín et al., 2023; Zhao et al., 2023), and there have been fewer studies based on the components of creativity, on verbal and figural creativity, and much less on creative profiles established by these variables.

The results of analyzing students' creative profiles could provide further insights into what students' creativity looks like and whether these profiles are related to intellectual and cognitive abilities.

Creativity profiles

Creativity is essentially a combined process associated with the elements of Guilford's theory of divergent thinking (DT) (1967), which comprises four key processes: fluency, flexibility, originality, and elaboration (Milgram and Livne, 2006; Runco & Acar, 2012). In essence, creativity involves fluency as the generation of a multitude of ideas; flexibility as the ability to switch between different perspectives or approaches; originality as the production of unique and novel solutions; and elaboration as the development and refinement of these ideas

(Handayani et al., 2021; Hendrik et al., 2022). Furthermore, creativity manifests itself in various forms, verbal creativity and figural creativity (Goff & Torrance, 2002).

Authors such as Chen et al. (2019) have described the nature of verbal and figural creativity, highlighting its unique cognitive mechanisms and neural underpinnings. Using neuroimaging techniques, they suggest that verbal creativity may rely more on regions associated with language processing and semantic integration, such as prefrontal regions, whereas figural creativity may involve visual-spatial processing areas, including the occipital and parietal lobes of the right hemisphere

Verbal and figural creativity processes can be distinguished in children and they are related in the sense that they both may draw on processes involved in DT and involve generating novel ideas and solutions through different modalities that may involve DT (Benedek & Fink, 2019). Whereas verbal creativity is primarily concerned with verbal expression and communication, figural creativity focuses on visual or spatial representations (Goff & Torrance, 2002). Despite these differences, there are common cognitive processes that underlie both types of creativity, and there may also be interactions between verbal and figural creative processes (Zhu et al., 2017).

Hence, it is likely that students can be distinguished with strong verbal creativity but weaker figural creativity, while others may demonstrate high abilities in both, and other combinations are possible. These combinations of different types of creativity could be called "profiles". In recent years, there has been a growing interest in exploring creativity profiles using latent profile analysis (LPA) across various domains. One notable study by Paek and Runco (2018) used LPA to examine creativity profiles in a sample of children and identified 3 distinct DT profiles, each characterized by unique combinations of fluency, originality and flexibility. Similarly, Stamatis and Weisman de Mamani (2022) used LPA to investigate distinct profiles of creative abilities in relation to psychopathology among young adults. Their findings revealed three distinct profiles characterized by different levels of convergent thinking (CT) and DT.

In addition, Goulet-Pelletier and Cousineau (2022) analyzed the profiles of creative students in a sample of university students and found five profiles based on academic aspects of perfectionism, excellence, motivation, academic self-concept and creative self-concept. However, we found no studies that relate creativity profiles to cognitive processes such as EF or intelligence in adolescents.

Creativity profiles and outcome variables

Understanding the interaction between individual differences in creativity profiles and key outcome variables, such as EF and intelligence, provides important insights into the multifaceted nature of creativity. Creativity, which encompasses both verbal and figural dimensions, emerges as a significant predictor of cognitive performance and academic achievement (Chrysikou, 2019; Gajda et al., 2017). By examining how different profiles of creative expression relate to these outcome variables, we aim to uncover the underlying mechanisms that shape cognitive abilities.

EF represent a set of higher-order cognitive processes responsible for goal-directed behaviors, encompassing functions such as inhibition, working memory, and cognitive flexibility (Diamond, 2013; Miyake et al., 2000). The relationship between creativity and EF has garnered considerable attention in recent years (Krumm et al., 2018; Pasarín-Lavín et al., 2024). While traditional views have often considered creativity as an independent construct, emerging research suggests a complex interdependence between it and EF (Wang et al.,2021; Zabelina et al., 2019). Authors such as Benedek et al., (2014) argue that EFs are fundamental to facilitating creative ideation and expression. Planning skills enable individuals to effectively structure and organise their thoughts, while working memory capacity influences the manipulation and maintenance of information during creative tasks, and cognitive flexibility—reflected in the ability to change—facilitates exploration of alternative perspectives and adaptive responses that are critical to creative problem solving (Baggetta and Alexander, 2016). Indeed, research has found positive associations between divergent thinking with EF (autores).

There are even studies, such as Lin and Lien (2013), that analyse working memory profiles and show that lower verbal working memory may be associated with higher DT scores. Similarly, de Vink et al. (2023) analysed working memory profiles with DT and indicated that good visual working memory may facilitate visual DT, whereas verbal DT may depend on more distributed variables.

Intelligence, on the other hand, is frequently related to creativity (Plucker et al., 2015). Authors such as Sternberg propose up to 5 types of relationships between these two variables: creativity as part of intelligence; intelligence as part of creativity; creativity and intelligence as three types of sets (overlapping, coincident and disjunct).

Even authors such as Gottfredson (2016)—based on the Cattell-Horn-Carroll (CHC) theory (Horn and Cattell, 1966; Carroll, 1993)—do not talk about creativity and intelligence,

but rather include creativity with the concepts crystallised intelligence (Gc) and fluid intelligence (Gf), relating creativity to fluid intelligence. There are also authors such as Renzulli (2021), who suggest that people with high abilities show high creativity and intelligence skills, seeing how these variables are related. Furthermore, authors such as Kim (2005) have noted that this relationship is weaker in samples of children, which may be because they are in the process of developing their cognitive abilities. Finally, studies such as Frith et al. (2021) have reported that intelligence and creativity share cognitive bases and are therefore clearly related.

There is evidence of a relationship between intelligence and creativity measured in a general way, but there are no studies that have related intelligence to different creative profiles. Analysing the relationship of different creativity profiles with EF and intelligence could offer new insights into these three cognitive abilities and the mechanisms related to them.

The Present Study

The aim of this study was to identify the creative characteristics of secondary school students in the Northern of Spain, in order to establish different creativity profiles. Analysis of the creative profiles allows us to observe differences that are not seen with individual creative elements. Moreover, factors related to EF and intelligence such as working memory, cognitive flexibility, and planning could also play a role in creativity models. This relationship has been explored in terms of individual differences between different profiles.

Creativity is considered an important determinant of academic and social development (Sawyer, 2020) and may be related to other cognitive constructs such as EF or intelligence (Karwowki et al., 2020; Krumm et al., 2018). Although many studies have related creativity to variables such as these, they have often analysed this relationship without considering people's different individual profiles. Many studies over recent years have taken a person-centered approach. The purpose of considering this kind of study is that showing the different creative profiles in relation to variables such as intelligence and EF could explain the inconsistency of results in variable-centred studies.

Based on the literature review presented above, we suggest that creative profiles are characterised by specific verbal and figural creative traits. We further hypothesise that there are three typical profiles: high verbal and low figural creativity scores, low verbal and high figural creativity scores, and high verbal and high figural creativity scores. Similarly, we suggest that profiles scoring highly on all creativity variables would score higher on measures

of intelligence and executive function than participants who score low on any type of creativity. Based on that, the study addressed the following hypotheses:

1. Three or four profiles will be identified due to the combination of the two types of creativity at different levels: high levels of verbal creativity with high levels of figural creativity, low levels of verbal creativity with low levels of figural creativity, high levels of verbal creativity with low levels of figural creativity and vice versa.
2. There will be no differences by gender in the different profiles. On the one hand, authors such as Taylor and Barbot (2021) found no statistically significant differences by gender, although male subjects scored higher in verbal creativity. Other authors such as (Matud et al., 2007) argued that gender differences were minimal and depended mainly on educational level, although they were only statistically significant in Figural Originality and Figural Creativity. This is also supported by authors such as He and Wong (2021) who noted that male subjects score higher in the figural domains of creativity.
3. There will be differences depending on the type of SEN. Various studies have reported that students with SEN may not show deficits in creativity. For example, Hoogman et al. (2020) found that students with ADHD may show high levels of DT; De Caroli and Sagone (2014) similarly argued that individuals with Down syndrome performed similarly to their neurotypical peers; and authors such as Šimčíková (2018) have claimed that people with dyslexia may show unique patterns of creativity.
4. There will be a relationship between creative profiles, EF and intelligence. There are no studies that relate creative profiles to cognitive variables such as EF and intelligence but authors such as Pasarín-Lavín et al. (2024), using a variable-based approach, have argued that correct development of EF is crucial for the development of creativity. This means that EF is important for the creation of innovative ideas and the ability to be flexible (Krumm et al., 2018). In the case of intelligence, authors such as Karwowki et al. (2020) have suggested that a basic level of intelligence is necessary for creative tasks, but high intelligence alone does not guarantee creativity. Similarly, Acar et al. (2018) emphasised the multifaceted nature of creativity, arguing that different aspects of intelligence, such as DT (generating multiple solutions) and CT (finding the best solution), influence several facets of creativity.

Method

Participants

A total of 94 (51.6%) boys and 88 (48.4%) girls aged between 12 and 16 (*M* = 13.34, *SD* = 1.19) participated in the study, with an average IQ of 101.44 (*SD* = 13.21). A total of 23 (12.68%) participants had Special Educational Needs (5 gifted, 7 with Attention-Deficit Hyperactivity Disorder (ADHD), 7 Specific Learning Difficulties (SLD) and 4 others). Participants were equivalent in terms of age and gender. The group consisted of secondary school students from two schools in Northern Spain. The inclusion criteria were being in the 1st to 4th grade of secondary education, attending school regularly and completing all the tests.

There were no statistically significant differences between gender with respect to age, t (180) = .868, p = .386; or *IQ*, t (180) = 1.54, p < .125) and gender distribution in total χ^2=.198; *df*=1; *p*=.657. Also, no significative statistical differences by grades were found for verbal creativity F (3, 176)=1.517; p = .143, $\eta 2$ = .025 or figural creativity F (3, 176)=1.659; p = .097, $\eta 2$ = .027. The distribution of participants by grades is shown in Table 1.

Table 1

Means (*M*) and Standard Deviation (*SD*) of IQ scores and age by grades.

	1st ESO	2nd ESO	3rd ESO	4rd ESO	Total	
N	60	67	15	40	182	
FSIQ *M* (*SD*)	104.85 (11.08)	109.56 (14.26)	104.76 (11.82)	109.75 (14.39)	106.88 (12.98)	F=2.095; p = .103, $\eta 2$ = .038
VCI *M* (*SD*)	105.48 (12.51)	103.96 (13.60)	114.13 (7.97)	106.49 (15.73)	105.85 (13.56)	F=2.401; p = .069, $\eta 2$ = .039
FRI *M* (*SD*)	98.57 (13.76)	93.18 (15.56)	105.73 (12.74)	96.18 (15.65)	96.65 (15.09)	F=3.464; p = .017, $\eta 2$ = .055
Age *M* (*SD*)	10.69 (3.05)	10.14 (3.10)	11.31 (2.81)	12.04 (2.80)	11.10 (2.98)	F=3.015; p = .032, $\eta 2$ = .053

Note: FSIQ= Full Scale IQ; VCI= Verbal Comprehension Index; FRI= Fluid Reasoning Index; M=Mean; SD=Standard Deviation

Instruments

3.2. Instruments and measures

3.2.1. Measures of Creativity

Creativity was assessed using the *PIC-J. Prueba de Imaginación Creativa para Jóvenes-Creative Imagination Test for Young People* (Artola, 2008). This test is designed to evaluate creativity in adolescents aged 12 to 18 years by tapping into their imagination. The assessment comprises four distinct games: the first three focus on verbal or narrative creativity, while the fourth assesses figural creativity. For the study, we used Game 2 and Game 4 from the PIC-J.

Game 2 draws inspiration from the Guilford Test (AUT; Guilford, 1967). In this adaptation, students are presented with a rubber tube as a stimulus and are instructed to come up with as many different uses for it as they can. This game assesses various components of verbal creativity, including Verbal Fluency, Verbal Flexibility, and Verbal Originality. In contrast, Game 4 is a graphical task inspired by the Torrance Test of Creative Thinking (TTCT; Torrance, 1998). In this task, students are required to complete four drawings using given lines and provide a title for each drawing. This segment evaluates aspects of figural creativity, including Figural Originality, Figural Elaboration, Figural Title, and Graphic Details.

The psychometric properties and reliability of the PIC-J were established by the authors, with a Cronbach's Alpha coefficient of .85 for the entire set of tests, indicating strong internal consistency and reliability.

PIC-J Interrater agreement. One of the most significant problems in creativity tests is the difficulty of two raters producing equivalent scores. For this reason, interrater agreement was used to check the validation of the scoring of the PIC-J. The degree of agreement was calculated using Cohen's weighted kappa statistic (*k*). Landis and Koch (1977) suggested the values be interpreted as follows: ≤ 0 as poor; 0.00–0.20 as slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement.

To implement Cohen's Kappa, the following was considered: (1) there are two raters who analyze at least 25% of the sample; (2) they have the same instructions and criteria for rating (3) the items to be rated are independent.

In an initial comparison, the *k* value was slight in several variables, with the highest values in *Verbal Fluency (*substantial, >0.61), *Verbal Flexibility* (moderate, > 0.41) and *Graphic Details* (moderate, >0.41). Twenty more subjects were evaluated after reaching an agreement between raters and *k* values were obtained that were almost perfect (*Verbal Fluency* and *Figural Elaboration*, >0.81) and substantial (*Verbal Flexibility*, *Verbal Originality*, *Figural Originality*, *Figural Title and Graphic Details*, >0.61).

3.2.2. Measures of EF

Nesplora Executive Functions - Ice Cream measures multiple components of EF and learning in children aged 8 and above through an immersive virtual reality (VR) experience.

This 20-45-minute test simulates a realistic multitasking scenario in which participants play the role of a new employee in an ice cream shop. Within this simulated environment, they are presented with a variety of rules and goals that reflect everyday challenges encountered in such an environment.

The ecological validity of the test is notable, as it accurately reflects the demands and complexities of real-life situations, enhancing its ability to effectively measure executive functioning. In addition, the *Nesplora Executive Functions - Ice Cream test* has the characteristics of an adaptive assessment, ensuring its adaptability to individual performance levels in planning, working memory, processing speed and cognitive flexibility. In particular, the reliability of the test variables is robust, with McDonald's omega coefficients ranging from .85 to .97, as demonstrated by Fernandez et al. (2023).

3.2.3. Measures of Intelligence

The Spanish adaptation of the WISC-V (Wechsler, 2014) was used in this study. The internal consistency of the Spanish version of the WISC-V was assessed using the two-half method. According to Amador and Forns (2019), the reliability coefficient for the Full Scale IQ (FSIQ) is reported to be 0.95.

In this study, the 7 primary subtests were used to calculate the *Full Scale IQ (FSIQ)*. These subtests include Similarities and Vocabulary for assessing Verbal Comprehension; Block Design for Visual Spatial; Matrix Reasoning and Weights for Fluid Reasoning; Digit Span for Working Memory; and Symbol Research for Processing Speed. These measures collectively contribute to the computation of the *Verbal Comprehension Index* (VCI) and the *Fluid Reasoning Index* (FRI).

Procedure and Data Analyses

The data were analyzed in several steps. First, the statistical properties of the variables were examined and missing values were treated using the multiple imputation procedure. Secondly, a latent class analysis was performed. To identify creativity profiles, seven measures were used, three of verbal creativity (fluency, flexibility and originality) and four of figural creativity (originality, elaboration, title and graphic details). Given that in the sample there were a small number of students with SEN, this variable was taken into account as a covariate when estimating the profiles. The creativity profiles were produced via LPA (Lanza et al., 2003) using Mplus v.6.11 (Muthén & Muthén, 1998–2017). Selection of the best model was based on the following criteria: the Lo-Mendell-Rubin Adjusted Likelihood Ratio Test (LMRT; Lo et al., 2001), the Akaike Information Criterion (AIC), the Information Criterion Bayesian Information Criterion (BIC) and the sample size-adjusted BIC (SSA-BIC), as well as the entropy value and sample size of each subgroup. Lower values in IAC, BIC and SSA-BIC indicate more parsimonious and better-fitting models, while the p value associated with the LMRT indicates whether the solution with more classes ($p < .05$) or fewer classes ($p > .05$) fits better (Nylund et al., 2007). Profiles were labelled following the criteria suggested by Wormington and Linnenbrink (2017). Raw scores were used for labeling and standardized scores were used as a visual aid. Third, the automatic Mplus DE3STEP command was used to estimate the differences between the profiles in the five criterion-external variables (IQ, working memory). Effect sizes were evaluated using Cohen's *d* criteria (Cohen, 1988): $d < 0.20$ = non-significant effect, $d \geq 0.20$ and $d < 0.50$ = small effect, $d \geq 0.50$ and $d < 0$ .80 = average effect; $d \geq 0.80$ = large effect. For all analyses, maximum likelihood estimation with robust standard error (MLR) was used.

This study was conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki), which reflects the ethical principles for research involving humans (World Medical Association, 2013). It was approved by the relevant Research Ethics Committee (code: CEISH-UPV/EHU, BOPV 32) and all procedures followed relevant laws and institutional guidelines. The manuscript data is available upon request from the author.

Results

Preliminary Analyses

Table 2

Pearson Correlations and Descriptive Statistics

	1	2	3	4	5	6	7	8	9	10	11	12
1. VFLU	-											
2. VFLE	.906**	-										
3. VOR	.830**	.785**	-									
4. FOR	.116	.158*	.051	-								
5. FELA	.099	.126	.120	.077	-							
6. FTIT	.068	.127	.036	.244**	.322**	-						
7. GDET	.079	.101	.063	.242**	.186*	.308**	-					
8. FSIQ	.221**	.275**	.203**	.128	.207**	.258**	.172*	-				
9. PLAN	.133	.139	.161*	.210**	.010	.094	.128	.255**	-			
10. MT	.068	.134	.088	.201**	.048	.212**	.081	.297**	.333**	-		
11. INTE	.073	.010	.035	-.130	.111	-.071	-.085	-.035	-.121	-.549**	-	
12. PERS	-.006	-.058	-.055	-.127	.063	-.161*	-.104	-.209	-.238**	-.605**	.685**	-
M	9.10	6.49	7.58	4.72	0.85	1.58	0.47	101.44	10.12	46.45	14.73	1.43
SD	5.23	3.08	5.78	2.39	1.24	1.80	0.76	13.21	3.91	7.24	19.70	2.09
SKW	0.96	0.38	1.11	0.21	1.88	1.04	1.79	-0.29	-0.84	-0.98	1.74	2.48
KUR	0.94	-0.08	0.92	-0.41	4.45	0.25	3.19	0.15	-0.62	0.78	4.54	7.70

Note: VFLU=Verbal Fluency; VFLE=Verbal Flexibility; VOR=Verbal Originality; FOR=Figural Originality; FELA=Figural Elaboration; FTIT=Figural Title; GDET=Graphic details; FSIQ= Full Scale IQ; PLAN=Planning; WM=Working Memory; INTE=Flexibility-Interference; PERS=Flexibility-Perseveration; M=Mean; SD=Standard Deviation; SKW=Skewness; KUR=Kurtosis

Table 2 provides the descriptive statistics of the variables, as well as the Pearson correlation matrix. Skewness and kurtosis values were within the intervals indicating a normal distribution (between -2 and +2; George & Mallery, 2010), except in specific cases (FELA kurtosis, FDET, Flexibility-interference and perseveration asymmetry). In terms of correlations, there was notable intercorrelation between the variables of each group (Verbal Creativity, Figural Creativity, external variables) but little intercorrelation between the groups of variables.

Identification of Creativity Profiles

To identify the creativity profiles, three latent class models were specified (models of two to four classes). The fit indices of the models are shown in Table 3. Model specification was stopped after four classes, given that a statistically non-significant LMRT was obtained ($LMRT_{4C} = 62.565$, $p > .05$) for this model. The LMRT test also indicated that the three-class model had a better fit to the data than the two-class model ($LMRT_{3C} = 143.110$, $p < .05$, and lower values in AIC, BIC and SSA-BIC than the two-class model). Although the four-class model gave the lowest values for AIC, BIC and SSA-BIC, the *p* value from LMRT was greater than .05 ($p = .7141$). Finally, the entropy values (classification power of the model) of the three-class model were greater than the values for the two- or four-class models. The classification accuracy of the three-class model was adequate (greater than .95 in all three classes).

Table 3

Fit of the Latent Class Models

	2 class Model	3 class Model	4 class Model
AIC	3351.217	3223.051	3177.150
BIC	3424.909	3325.580	3308.515
SSA-BIC	3352.065	3224.232	3178.662
LMRT	296.880	143.110	62.565
(*p* LMRT)	(0.0304)	(0.0336)	(0.7141)
Entropy	0.893	0.903	0.884
Size $n \leq 5\%$	0	0	0

Note.: AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; SSA-BIC = Sample-Size-Adjusted BIC; MLRT = Lo-Mendell-Rubin Adjusted Likelihood Ratio Test; Size $n \leq 5\%$ = number of classes with fewer than 5% of subjects the total sample; Entropy = quality classification of subjects into classes.

Description of the Creativity Profiles

The selected model shows three well-differentiated groups of subjects based on their creativity profiles. However, the three groups had similarly low levels of figural creativity. Therefore, the differentiation of the three profiles is due to the levels of verbal creativity. Specifically, there is a large group of individuals (52.20%) with a profile characterized by a medium-low level in the three dimensions of verbal creativity (LVC/MFC profile). Likewise, a second, reasonably sized, group of individuals (33.52%) had average values in the seven dimensions of creativity (MVC/MFC profile). Finally, there was a smaller third group (14.28%) characterized by high levels in the three dimensions of verbal creativity and medium-low values in figural creativity (HVC/MFC profile). Although in general there were no gender differences in the sample (girls: 48.4%, boys: 51.6%), there were differences within the profiles. Specifically, there were more girls than boys in the low creativity profile (53.7% and 46.3%, respectively), while in the other profiles, boys predominated, mainly in the high verbal creativity profile (average profile: 53.3% boys), but not in medium profile (46.7% boys). In terms of special educational needs, there were more NEAE individuals (29.6%) in the high verbal creativity group, and fewer (6.7%) in the medium creativity level group.

Table 4 provides the means and standard deviations of each of the seven dimensions of creativity within each profile. In order to compare the three profiles, scores were standardized ($M = 0$, $SD = 1$). With *z* scores, Figure 1 provides a graphical representation of each creativity profile.

Table 4

Means, estimation errors and confidence intervals corresponding to the estimates for the students in the five classes

	N (%)	Means (*z*)	S.E.	Lower 5%	Upper 5%
Profile LVC/MFC	95 (52.20%)				
VFLU		5.25 (-0.728)	0.057	-0.823	-0.634
NFLE		4.16 (-0.754)	0.080	-0.886	-0.622
VOR		3.61 (-0.687)	0.054	-0.776	-0.598
FOR		4.59 (0.057)	0.107	-0.233	0.120
FELA		0.66 (-0.146)	0.089	-0.293	0.000
FTIT		1.37 (-0.100)	0.121	-0.300	0.099
GDET		0.47 (0.015)	0.126	-0.192	0.223
Profile MVC/MFC	61 (33.52%)				
VFLU		11.15 (0.388)	0.109	0.208	0.567
VFLE		8.25 (0.559)	0.093	0.405	0.712
VOR		8.99 (0.262)	0.119	0.066	0.458
FOR		4.82 (0.042)	0.115	-0.146	0.231
FELA		1.10 (0.191)	0.159	-0.071	0.452
FTIT		2.00 (0.204)	0.169	-0.074	0.481
GDET		0.43 (-0.066)	0.153	-0.317	0.185
Profile HVC/MFC	26 (14.28%)				
VFLU		18.07 (1.740)	0.193	1.422	2.058
VFLE		10.78 (1.426)	0.207	1.086	1.767
VOR		18.41 (1.887)	0.146	1.646	2.128
FOR		4.93 (0.107)	0.228	-0.268	0.482
FELA		1.00 (0.082)	0.206	-0.257	0.420
FTIT		1.37 (-0.117)	0.186	-0.423	0.188
GDET		0.52 (0.101)	0.213	-0.249	0.452

Note: N (%) number of students in the class and percentage. SE=Estimation error. Confidence intervals: Lower 5% and Upper 5%. LVC/MFC=Low verbal creativity/Medium figural creativity; MVC/MFC=Medium verbal creativity/Medium figural creativity; HVC/MFC=High verbal creativity/Medium figural creativity; VFLU=Verbal Fluency; VFLE=Verbal Flexibility; VOR=Verbal Originality; FOR=Figural Originality;

FELA=Figural Elaboration; FTIT=Figural Title; GDET=Graphic details; Measurement scales: VFLU (min: 0, max: 38); VFLE (min: 0, max: 36); VOR (min: 0, max: 38); FOR (min: 0, max: 12); FELA (min: 0, max: 8); FTIT (min: 0, max: 8); FDET (min: 0, max: 16).

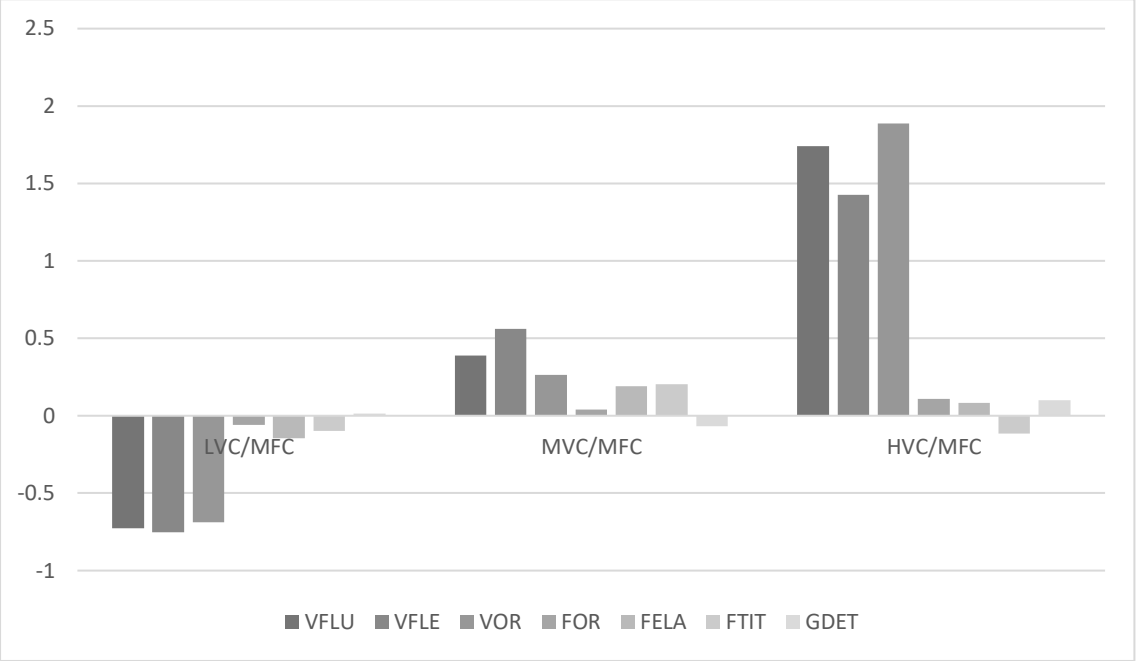


Figure 1. Graphical representation of creativity profiles. LVC/MFC (*n* = 95), MVC/MFC (*n* = 61), HVC/MFC (*n* = 26).

Relationship Between the Creativity Profiles and Outcome Variables

The means and standard errors are provided in Table 5. The data suggest few differences between the three profiles in the five criterion variables, especially in working memory, planning, flexibility-interference, and perseveration. Overall, the equality tests of means showed only marginally significant differences between the creativity profiles in terms of IQ (χ^2 = 5.010, p = 0.082), and statistically non-significant differences for the other four variables: planning (χ^2 = 3.421, p = 0.181); working memory (χ^2 = 2.181, p = 0.336); Flexibility-interference (χ^2 = 0.730, p = 0.694); and flexibility-perseveration (χ^2 = 1.023, p = 0.600).

Table 5

Means and standard errors of each profile in the criterion variables

	LVC/MFC	MVC/MFC	HVC/MFC
IQ			
M	99.238	103.817	103.783
S.E.	1.493	1.531	2.266
Planning			
M	9.581	10.625	10.868
S.E.	0.434	0.495	0.656
Working Memory			
M	45.656	47.406	47.061
S.E.	0.815	0.973	0.995
Flex-Interference			
M	14.868	13.528	17.059
S.E.	2.131	2.580	3.290
Flex-Perseveration			
M	1.566	1.233	1.417
S.E.	0.254	0.226	0.343

Note: LVC/MFC (Low verbal creativity/Medium figural creativity); MVC/MFC (Medium verbal creativity/Medium figural creativity); HVC/MFC (High verbal creativity/Medium figural creativity). Measurement scales: Planning (min: 1, max: 14); Working Memory (min: 20, max: 56); Flexibility-Interference (Min: -29, max: 100); Flexibility-Perseveration (Min: 0, Max: 13).

Pairwise comparisons (Table 6) show that there were only statistically significant differences comparing the LVC/MFC and MVC/MFC ($\chi^2 = 4.398$, $p = 0.036$, $d = 0.341$) groups in the IQ variable (small effect size), and only marginally significant differences comparing IQ between LVC/MFC and HVC/MFC ($\chi^2 = 2.788$, $p = 0.095$).

Table 6

Multiple comparisons between creativity profiles in the five criterion variables

	χ^2	*p* <.	*Cohen's d*
IQ			
LVC/MFC vs. MVC/MFC	4.398	0.036	0.341
LVC/MFC vs. HVC/MFC	2.788	0.095	—
MVC/MFC vs. HVC/MFC	0.000	0.990	—
Plannig			
LVC/MFC vs. MVC/MFC	2.360	0.124	—
LVC/MFC vs. HVC/MFC	2.666	0.103	—
MVC/MFC vs. HVC/MFC	0.086	0.769	—
Working Memory			
LVC/MFC vs. MVC/MFC	1.762	0.184	—
LVC/MFC vs. HVC/MFC	1.200	0.273	—
MVC/MFC vs. HVC/MFC	0.060	0.806	—
Flexibility-Interference			
LVC/MFC vs. MVC/MFC	0.155	0.693	—
LVC/MFC vs. HVC/MFC	0.313	0.576	—
MVC/MFC vs. HVC/MFC	0.692	0.406	—
Flexibility-Perseveration			
LVC/MFC vs. MVC/MFC	0.888	0.346	—
LVC/MFC vs. HVC/MFC	0.121	0.728	—
MVC/MFC vs. HVC/MFC	0.196	0.658	—

Note: LVC/MFC (Low verbal creativity/Medium figural creativity); MVC/MFC (Medium verbal creativity/Medium figural creativity); HVC/MFC (High verbal creativity/Medium figural creativity).

Discussion

The present study was the first to use LPA to understand the structure of verbal and figural creativity through different creative profiles. We also analysed whether there were statistically significant differences according to gender and type of SEN and the relationship between these creative profiles, EF and intelligence.

Creativity profiles

In line with hypothesis, the best-fitting model had three classes (the four-class model did not improve on the three-class model). This model indicated three student profiles that did not match previously hypothesised profiles as figural creativity in all three profiles was at a medium level. Consistency or inconsistency with previous studies cannot be stated, as LPA-based studies focus on other creativity variables. On the one hand, the results from Paek and Runco (2018) indicated three groups with their own profiles of fluency, originality and flexibility: group 1 with high originality, group 2 with low originality and group 3 with all

variables uniformly low originality. On the other hand, authors such as Stamatis and Weisman de Mamani (2022) indicated 4 combinations of CT and DT. Individuals with high levels of CT, but medium-low DT; individuals with high levels of both CT and DT; individuals with medium-low CT and medium-high DT; and individuals with low levels in both dimensions of creativity.

Overall, there were no statistically significant differences between boys and girls within the study and there was parity (girls: 48.4%, boys: 51.6%). However, there were some striking differences within the different creativity profiles. While the low creativity profile had a slight majority of girls, in the other profiles, especially the high verbal creativity profile, there was predominance of boys. This is in line with the study from Taylor and Barbot (2021) who, although they did not find statistically significant differences by gender, noted that men tend to score higher in verbal creativity. In contrast, it does not agree with studies such as Matud et al. (2007) and He and Wong (2021), who argued that male subjects tended to outperform female subjects, specifically in the figurative domains of creativity.

However, it is important to note that while gender may not be a determinant of creative ability, contextual factors such as special needs may influence an individual's creative development. For example, within the group characterised by high levels of verbal creativity, there was a significant proportion of individuals with SEN (29.6%). In contrast, the medium creativity group had a lower prevalence (6.7%). This is in line with studies by authors such as Kasirer et al. (2020), McBride et al. (2021) and Nakano et al. (2021), who argued that students with ASD, ADHD or giftedness may have unique verbal creative abilities. These differences highlight the importance of tailored educational interventions to support diverse creative talents and address different learning needs, regardless of gender.

Relationship Between the Creativity Profiles and Outcome Variables

First of all, the outcome variables were more or less correlated with the verbal and figural creativity sub-variables. For example, the FSIQ correlated remarkably strongly with all the creativity variables, except for Graphic Detail, which correlated moderately, and Figural Originality, which did not. This is consistent with authors such as Hendrik et al. (2018) who reported a correlation between intelligence and the creativity sub-variables, finding a weaker correlation in Figural Originality, in our study non-existent. On the other hand, Planning and Working Memory correlated with some of the creativity variables. For example, Planning exhibited a strongly positive correlation with Figural Originality and a

moderate correlation with Verbal Originality; and Working Memory had a strongly positive correlation with Figural Originality and Figural Title. As this was an immersive, VR-based assessment of EF, the working memory task in the study was visual, which is consistent with studies such as Vink et al. (2023) and Lu et al. (2021), who claimed that high visual working memory improves figurative creative tasks.

Several studies (Krumm et al., 2018; Palmiero et al., 2022) have examined the relationship between creativity and EF, with mixed results. Some research has suggested a positive relationship, indicating that those with higher EF skills tend to have higher levels of creativity (). This perspective postulates that EFs play a crucial role in facilitating the cognitive processes involved in creative ideation.

In contrast, other studies suggest that certain EFs may be more closely related to specific aspects of creativity. For example, working memory capacity may be particularly important for retaining and manipulating the diverse information required for creative problem solving (Orzechowski et al., 2023), or shifting and inhibition may support creative thinking (Wang et al., 2021).

However, it is important to note that the relationship between creativity and EF is likely to be bidirectional and influenced by a variety of factors, such as individual differences or environmental contexts. For this reason, LPA can be used to further explore this interaction between creativity and EF.

Analyses of the relationship between the profiles and outcome variables suggest that although there are some discernible differences in intelligence scores between specific creativity profiles, the differences are relatively subtle. Furthermore, the absence of significant differences in other criterion variables, such as Working Memory, Planning and Cognitive Flexibility (Interference and Perseveration), suggests a degree of similarity in cognitive functioning between the different creativity profiles of secondary school students. These findings highlight the complexity of the relationship between creativity, intelligence and EF and underline the need for further research to illuminate the underlying mechanisms driving these associations.

Implications

This study investigated the existence of different creativity profiles (verbal and figural) and whether these profiles were related to variables such as intelligence and EF using LPA.

The results confirmed the existence of heterogeneous groups in terms of creativity profiles and the relationship of these profiles with intelligence, but not with EF.

The study demonstrated the benefits of a person-centred approach to exploring individual differences in more detail by comparing constructs between and within students**.**

The identification of students' creative profiles could provide useful information to guide students' educational practice. This study demonstrated the independence of creativity as a cognitive construct by investigating verbal and figural creativity in relation to cognitive variables. It may serve as a basis for future research on individual differences in creativity, intelligence and EF.

Limitations and future research

Although some studies suggest a general positive relationship between EF and creativity, this study highlights the need to recognize that the nature and extent of this relationship may vary depending on the specific demands of different creative tasks. In this case, one limitation of the study is the use of a partial rather than a full DT-based test of creativity, which may have influenced the low figural creativity scores. Therefore, accurate measurement of DT should be explored in future research using other tests.

In addition, the small sample size in this group is clearly a critical issue that reduces statistical power; future research should replicate this in a larger sample.

Along similar lines, it is important to recognise the limitations inherent in the assessment of creativity and executive function, particularly in relation to people with special educational needs. Standardised tests of creativity and EF are often designed and standardised on the basis of neurotypical populations, potentially overlooking the diverse cognitive profiles and unique learning characteristics of people with SEN. As such, adaptations and adjustments may be required to ensure that assessments accurately capture the creative potential and executive functioning abilities of all individuals, regardless of their cognitive or developmental differences.

In light of these considerations, future research should be consistent with inclusive assessment methods and practices that take into account the diverse cognitive profiles of individuals with SEN. Finally, future research could aim to demonstrate how identification of profiles can be useful in choosing which educational practices to follow, thus demonstrating that one choice or another, depending on the profile, can improve performance.

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05

DISCUSIÓN Y CONCLUSIONES

5.1. DISCUSIÓN GENERAL

La presente Tesis Doctoral ha tratado de profundizar en la compleja interrelación entre la creatividad, específicamente el pensamiento divergente, y las FE en adolescentes. A través de una combinación de análisis de la literatura y estudios empíricos, se ha investigado cómo estas habilidades cognitivas no solo se desarrollan de manera independiente sino también cómo interactúan para influir en el aprendizaje de los jóvenes. Esta investigación se ha estructurado en tres fases complementarias, permitiendo una exploración integral y profunda de este vínculo cognitivo, con el resultado de tres estudios publicados y dos trabajos complementarios enviados para publicación.

En la **primera fase**, se llevó a cabo una revisión sistemática de la literatura existente sobre la relación entre creatividad y FE en la infancia y la adolescencia. Esta revisión, basada en la metodología PRISMA, incluyó investigaciones empíricas previas y tuvo como objetivo identificar el estado actual del conocimiento. Los resultados de esta fase proporcionaron el marco teórico y conceptual necesario para construir una base conceptual sólida que guiara las siguientes fases de la investigación, resaltando la falta de consenso sobre el impacto de las FE en el desarrollo de la creatividad y la necesidad de estudios más focalizados en poblaciones adolescentes neurodiversas.

La **segunda fase** consistió en dos estudios preliminares. El primero, centrado en el análisis del desarrollo evolutivo de las FE y la creatividad en adolescentes, aplicando métodos estadísticos para identificar las trayectorias del desarrollo y la relación de estas habilidades con la inteligencia. El segundo estudio, contando con una división del grupo en muestra de estudiantes neurotípicos y estudiantes neurodivergentes, investigó cómo el perfil neurocognitivo influye en la creatividad y las FE. Estos estudios preliminares permitieron establecer una base comparativa y comprensiva, resaltando las diferencias y similitudes en el desarrollo cognitivo teniendo en cuenta la edad y el perfil neurodiverso. Además, cabe destacar la utilización de la herramienta *Nesplora Executive Functions – Ice Cream* en esta Tesis Doctoral resulta, no solo por la innovación en el uso de entornos de RV para la evaluación de las FE, sino también por su capacidad de proporcionar una experiencia de evaluación más realista y dinámica que las pruebas tradicionales. Al simular un entorno cotidiano, como una tienda de helados, esta herramienta permite evaluar las FE, como la planificación, memoria de trabajo, flexibilidad cognitiva y velocidad de procesamiento, en un contexto que refleja de manera más fiel los retos a los que los adolescentes se enfrentan en la vida diaria.

La validez ecológica es uno de los principales argumentos a favor del uso de la RV en la evaluación cognitiva. Según Fernández et al. (2023), la experiencia inmersiva que ofrece *Nesplora Executive Functions – Ice Cream* reproduce un entorno multitarea que emula situaciones del mundo real, lo que facilita una evaluación más precisa del comportamiento y la respuesta cognitiva de los individuos en condiciones que son más comparables a sus actividades diarias. Esta característica se alinea con investigaciones previas que señalan que las evaluaciones realizadas en entornos ecológicamente válidos pueden mejorar la precisión en la medición de capacidades cognitivas complejas (Rizzo et al., 2023). Además, el uso de la RV permite capturar de manera detallada las interacciones del participante con el entorno, midiendo aspectos como el tiempo de reacción, los errores cometidos y la capacidad de gestionar múltiples tareas simultáneamente.

Otra ventaja clave de este enfoque es su potencial para aumentar la motivación y el compromiso de los participantes, especialmente en adolescentes, dado el atractivo y la naturaleza inmersiva de la RV. Estudios como los de Rizzo et al. (2019) destacan que la RV puede mejorar la adherencia y la atención en las evaluaciones, en comparación con métodos más convencionales, lo que puede llevar a resultados más fiables.

Finalmente, la **tercera fase** involucró un estudio complementario que se enfocó en un análisis de perfiles latentes, cuyo objetivo fue identificar distintos grupos de adolescentes con perfiles creativos específicos y explorar cómo estos se asocian con variables neurocognitivas, tales como la inteligencia o la neurodiversidad.

En conjunto, los resultados obtenidos en las fases de la investigación subrayan la importancia de integrar una perspectiva contextual y empírica en el estudio de la creatividad y las FE. Esta investigación ha tenido como objetivo general el de investigar la relación entre las FE y la creatividad en adolescentes y que se pueden concretar en los objetivos generales de cada estudio.

1. Analizar la relación entre las funciones ejecutivas y la creatividad en niños y adolescentes, evaluando cómo estas capacidades cognitivas interactúan y se influyen mutuamente.
2. Examinar el desarrollo evolutivo de las funciones ejecutivas y la creatividad a lo largo de la adolescencia, identificando cambios significativos y su relación.

3. Estudiar las dos variables en diferentes perfiles neurocognitivos, destacando las posibles diferencias y similitudes en los patrones de desarrollo.
4. Identificar perfiles creativos en adolescentes, considerando factores como la neurodiversidad, el género, la inteligencia y la edad, y explorando las implicaciones de estos perfiles en su desarrollo cognitivo.

El desarrollo de esta Tesis Doctoral se aborda a través de la respuesta a las preguntas de investigación planteadas y que se analizan en el contexto de los objetivos previamente establecidos.

1. ¿Qué evidencia existe sobre la relación entre las funciones ejecutivas y la creatividad en niños y adolescentes?
2. ¿Cómo evolucionan y se relacionan las FE y la creatividad a lo largo de la adolescencia?
3. ¿Cómo varían estas variables según el perfil neurocognitivo de los estudiantes?
4. ¿Qué perfiles creativos se encuentran en la adolescencia y cómo se relacionan con otras variables?

5.1.1. Relación entre Creatividad y Funciones Ejecutivas en adolescentes

La revisión sistemática realizada como **Estudio Publicado 1** de esta Tesis Doctoral: *"Relationship between executive functions and creativity in children and adolescents: a systematic review"*, responde al primer objetivo de la presente Tesis Doctoral: **analizar la relación entre las FE y la creatividad en niños y adolescentes**, evaluando cómo estas capacidades cognitivas interactúan y se influyen mutuamente. Los resultados de esta investigación confirman que existe una relación significativa entre ciertas FE y la creatividad en adolescentes, especialmente en lo que respecta a la flexibilidad cognitiva. Estudios como el de Bai et al. (2021), coinciden en que la flexibilidad es un factor clave que facilita la creatividad, debido a que permite a los adolescentes generar respuestas originales y adaptarse a situaciones nuevas de manera más eficaz. Este hallazgo concuerda con estudios previos (Diamond, 2013; Miyake et al., 2000) que sugieren que la capacidad de alternar entre tareas o enfoques mentales está directamente relacionada con la producción de ideas creativas. En contraste, la inhibición parece tener una relación inversa con la creatividad, dado que un menor control inhibitorio facilita la generación de ideas novedosas al permitir respuestas menos convencionales (Sharma y Babu, 2020; Roskos-Ewoldsen et al., 2009).

En cuanto a otras FE como la memoria de trabajo, los resultados fueron menos concluyentes. No se encontraron evidencias sólidas que relacionaran la memoria de trabajo con la creatividad en esta muestra de adolescentes, lo cual es consistente con investigaciones previas, como las de Sharma y Babu (2020), que señalaron que las pruebas estándar de creatividad, como el Test de Pensamiento Creativo de Torrance (TTCT; Torrance, 1998), no exigen una alta carga en memoria de trabajo. Esto podría explicar por qué algunas FE como la memoria de trabajo no parecen tener un impacto directo en la capacidad creativa.

Por otro lado, la atención también ha demostrado jugar un papel importante en la creatividad, aunque de una manera inversa a lo esperado. Los adolescentes con niveles más bajos de atención tendían a generar respuestas más originales, lo que sugiere que una menor capacidad de focalización podría permitir un pensamiento más divergente y menos estructurado, favoreciendo la creatividad. Este fenómeno está respaldado por estudios recientes que destacan el papel del déficit atencional en la producción de respuestas creativas más originales (Arya y Maurya, 2016; van Dijk et al., 2020).

Además, se observó una gran diversidad en las herramientas de evaluación tanto para las FE como para la creatividad. Mientras que las pruebas para la creatividad, como TTCT, Alternative Uses Task (AUT; Guilford, 1967) o CREA. Inteligencia Creativa (Corbalán et al., 2003) mostraron cierta estabilidad en su uso, las pruebas para las FE presentaron una variabilidad considerable dependiendo de la función evaluada. Las pruebas más comunes incluyeron el Wisconsin Card Sorting Test (WCST; Heaton et al., 1981) para la flexibilidad, el subtest de dígitos del WISC-IV (Wechsler, 2003) para la memoria de trabajo, y la prueba de Stroop para la inhibición. Esta diversidad sugiere la necesidad de mayor estandarización en las pruebas utilizadas, ya que la estandarización de las medidas permitiría generalizar los resultados con mayor rigor y fiabilidad.

Esta investigación sugiere que ciertas FE, especialmente la flexibilidad cognitiva y el control inhibitorio, desempeñan un papel crucial en la creatividad en adolescentes. Estos resultados enfatizan la importancia de continuar investigando esta interacción, con el fin de diseñar intervenciones educativas que fomenten tanto las FE como la creatividad en esta etapa del desarrollo.

5.1.2. Desarrollo evolutivo de la Creatividad y las Funciones Ejecutivas

El segundo objetivo de esta Tesis Doctoral, **examinar el desarrollo evolutivo de la creatividad y las FE a lo largo de la adolescencia, identificando cambios significativos y relaciones**, encuentra respuesta en los resultados obtenidos en el **Estudio Publicado 2**: *"Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity"*. La investigación muestra que las FE, especialmente la planificación y la memoria de trabajo, presentan un desarrollo evolutivo significativo en adolescentes. Los resultados indican que las puntuaciones de estas habilidades aumentan progresivamente desde el primer año hasta el cuarto año de educación secundaria, lo que concuerda con estudios como el de Davidson et al. (2006), que sostienen que algunas FE, como la flexibilidad cognitiva, no se desarrollan completamente hasta los 19 años. No obstante, estos hallazgos contradicen a autores como Filippetti (2011), quien sostiene que la planificación no muestra una evolución con la edad, lo que podría explicarse por las diferencias en los rangos de edad estudiados y el tipo de evaluación utilizada.

En cuanto a la creatividad medida como pensamiento divergente, los resultados sugieren que, a diferencia de las FE, esta muestra un comportamiento diferente según la modalidad evaluada. Los componentes de la creatividad verbal (fluidez, originalidad verbal y elaboración de títulos gráficos) se mantienen estables a lo largo de la adolescencia, mientras que la creatividad figurativa (originalidad y detalles gráficos) presenta una tendencia decreciente conforme avanza la escolarización. Esto contrasta con estudios como el de Hong y Milgram (2010), quienes afirman que la creatividad, medida a través del pensamiento divergente, se desarrolla de forma continua durante el crecimiento infantil. La razón de esta discrepancia podría radicar en que los adolescentes desarrollan la fluidez verbal a un ritmo más constante, mientras que la calidad de las respuestas mejora conforme adquieren nuevos conocimientos y habilidades, como sugieren Kleibeuker et al. (2016). Además, autores como Woodel-Johnson et al. (2012) señalan que el proceso creativo se expresa de manera distinta en cada etapa del desarrollo, lo que explicaría las diferencias observadas entre estudiantes de 12 y 16 años.

Añadido a todo lo anterior, estudios como el de Ardila (2018) o Benedek et al. (2014) afirman que las FE tienen una clara relación predictiva con la inteligencia, de manera más específica, la flexibilidad cognitiva y la memoria de trabajo. Por el contrario, no se pudo demostrar que el DT predijera la inteligencia. Esto podría deberse a que los

centros educativos actuales contribuyen al desarrollo de la inteligencia, pero apenas a la creatividad (Arya y Maurya, 2016).

Estos resultados subrayan la complejidad del desarrollo de la creatividad durante la adolescencia, con manifestaciones variadas dependiendo del tipo de creatividad evaluada (verbal o figurativa) y sugieren que, mientras las FE mejoran notablemente con la edad, el pensamiento divergente figurativo puede estar influenciado por otros factores educativos y contextuales que requieren una mayor atención en investigaciones futuras.

La evidencia obtenida en esta investigación destaca que las FE, como la planificación y la memoria de trabajo, evolucionan de manera significativa a lo largo de la adolescencia, influyendo en el desarrollo de la creatividad. Aunque la creatividad verbal mantiene una estabilidad relativa, la creatividad figurativa parece mostrar una evolución decreciente, lo que invita a reflexionar sobre la necesidad de fomentar el desarrollo creativo en todas sus facetas durante esta etapa crítica de la vida.

5.1.3. Creatividad y Funciones Ejecutivas en diferentes perfiles neurocognitivos

En el **Estudio Publicado 3**: *"Divergent thinking and Executive functions in children: A developmental perspective based on intellectual capacity"*, se da respuesta al tercer objetivo de esta Tesis Doctoral: **comparar la creatividad y las FE entre adolescentes neurotípicos y neurodivergentes**. Los resultados indican que los componentes de la creatividad, medida como pensamiento divergente y los de las FE, medidos con RV, pueden variar según el perfil neurodiverso de los estudiantes.

Esta investigación examinó las diferencias en la creatividad (tanto verbal como figurativa) y en los componentes de las FE, incluyendo la memoria de trabajo, la planificación y la flexibilidad, entre cinco grupos distintos de estudiantes: neurotípicos, con TDAH, con dislexia, con DI y con altas capacidades.

Los resultados revelan diferencias significativas en **creatividad verbal** entre los grupos. Los estudiantes con TDAH destacaron en originalidad verbal, superando a los estudiantes neurotípicos y a los estudiantes con altas capacidades, y también obtuvieron puntuaciones superiores en flexibilidad verbal y fluidez verbal. Este hallazgo respalda las observaciones de Hoogman et al. (2020), quienes sugieren que los estudiantes con TDAH pueden exhibir ventajas en tareas divergentes debido a una menor inhibición cognitiva (Hoogman et al., 2020; Radel et al., 2015). En contraste, los estudiantes con DI obtuvieron las puntuaciones más bajas en creatividad verbal, como también se

observó en De Caroli y Sagone (2014), lo que podría estar relacionado con la falta de adaptación en las tareas de evaluación (Kooijmans et al., 2022).

En cuanto a la **creatividad figurativa**, aunque no se observaron diferencias estadísticamente significativas a nivel general, los estudiantes con TDAH mostraron bajas puntuaciones en título figurativo y detalles figurativos, lo que podría explicarse por dificultades en la atención a detalles espaciales (González-Carpio et al., 2017). Por otro lado, los estudiantes con dislexia exhibieron alta originalidad figurativa, similar a los neurotípicos, lo que es consistente con los hallazgos de Lam y Tong (2021) que afirmaron que los estudiantes con dislexia pueden mostrar una buena creatividad figurativa. Los estudiantes con altas capacidades mostraron consistentemente altas puntuaciones en creatividad figural, apoyando los resultados de Renzulli y Reis (2020).

En términos de **FE**, se encontraron diferencias notables entre los grupos. Los estudiantes con DI mostraron resultados más altos en flexibilidad cognitiva, medida como interferencia y perseveración, indicando un rendimiento deficiente en estas áreas, en consonancia con Erostarbe-Pérez et al. (2022) y Danielsson et al. (2012) lo que puede deberse a dificultades asociadas al control inhibitorio, la flexibilidad cognitiva, el procesamiento de la información y la autorregulación, entre otros factores asociados a su condición. Los estudiantes con TDAH, en cambio, tuvieron un desempeño similar al de los estudiantes neurotípicos en memoria de trabajo y planificación, pero presentaron altas puntuaciones en flexibilidad, medida como interferencia y perseveración, reflejando problemas en inhibición y flexibilidad (Pazvantoğlu et al., 2012).

Los estudiantes con altas capacidades destacaron en memoria de trabajo, como lo indica León (2020) que asegura que desatacan en habilidades relacionadas con este dominio. Por último, los estudiantes con dislexia mostraron resultados comparables a los estudiantes neurotípicos en FE, salvo en memoria de trabajo, lo cual se alinea con Barbosa et al. (2019) que asegura que el alumnado con dislexia muestra déficits en memoria de trabajo, pero no en otras FE como la planificación.

Los hallazgos de este estudio subrayan la importancia de enfoques educativos personalizados que reconozcan y aprovechen el potencial creativo y cognitivo de los estudiantes neurodiversos, al tiempo que abordan sus perfiles cognitivos y desafíos únicos. Como sugieren los resultados, la mayoría de los estudiantes con NEAE pueden mostrar áreas específicas de fortaleza y debilidad en términos de creatividad verbal y

figurativa, así como en FE, lo que sugiere la necesidad de intervenciones adaptadas a estos perfiles únicos.

5.1.4. Perfiles creativos en la adolescencia

Para completar los estudios anteriores se realiza el **Estudio Complementario 1** titulado *"Latent Profile Analysis of Creativity: Relations with Intelligence and Executive Functions"* que aborda el cuarto objetivo de esta Tesis Doctoral, que es **identificar perfiles creativos en adolescentes, teniendo en cuenta factores como la neurodiversidad, el género, la inteligencia y la edad, y explorar las implicaciones de estos perfiles en su desarrollo cognitivo.**

El análisis de perfiles latentes (LPA) identificó tres perfiles de creatividad en los adolescentes. A diferencia de los modelos teóricos previos que proponían perfiles basados en variables específicas como fluidez, originalidad y flexibilidad (Paek y Runco, 2018), o combinaciones de creatividad convergente y divergente (Stamatis y Weisman de Mamani, 2022), el estudio encontró que todos los perfiles presentaban un nivel medio de creatividad figurativa. Este hallazgo destaca la necesidad de enfoques más matizados para clasificar los perfiles creativos, ya que los resultados no se alinearon completamente con las clasificaciones tradicionales.

Aunque no se encontraron diferencias significativas por género en los perfiles creativos, se observó una tendencia interesante: el perfil de alta creatividad verbal tendió a estar compuesto en su mayoría por chicos, mientras que el perfil de baja creatividad verbal tenía una ligera mayoría de chicas. Este patrón es coherente con el estudio de Taylor y Barbot (2021), que encontró que los hombres tienden a puntuar más alto en creatividad verbal, aunque no encontró diferencias significativas. En contraste, otros estudios (Matud et al., 2007; He & Wong, 2021) sugieren que los hombres podrían superar a las mujeres en dominios figurativos de creatividad, lo cual no se observó en este estudio.

Además, el estudio reveló que un 29.6% de los estudiantes con alta creatividad verbal tenían NEAE, en comparación con un 6.7% en el grupo de creatividad media. Esto está en línea con la investigación de Kasirer et al. (2020), McBride et al. (2021), y Nakano et al. (2021), que destacan la presencia de habilidades creativas verbales únicas en estudiantes con TDAH, autismo y altas capacidades.

Por otro lado, los resultados mostraron que el CI total se correlacionaba fuertemente con la mayoría de las variables de creatividad, salvo con la originalidad figurativa. Esto coincide con Hendrik et al. (2018), quienes encontraron una correlación entre inteligencia y subvariables de creatividad, aunque la correlación con originalidad figurativa fue débil en nuestro estudio. Además, se observó que la planificación y la memoria de trabajo se correlacionaron positivamente con variables de creatividad, como originalidad figurativa y título figurativo, lo que refuerza los hallazgos de Vink et al. (2023) y Lu et al. (2021) sobre la importancia de la memoria de trabajo visual en tareas creativas figurativas.

Las investigaciones sobre la relación entre creatividad y FE han mostrado resultados mixtos. Algunos estudios sugieren que una mayor capacidad en FE se asocia con niveles más altos de creatividad (Krumm et al., 2018; Palmiero et al., 2022), mientras que otros indican que ciertas FE, como la memoria de trabajo, son particularmente relevantes para la creatividad (Orzechowski et al., 2023; Wang et al., 2021). Este estudio refuerza la complejidad de la relación entre creatividad, las FE y otras variables como la inteligencia destacando la utilidad de LPA para explorar estas interacciones.

Los hallazgos subrayan la importancia de un enfoque centrado en la persona para entender las diferencias individuales en creatividad. La identificación de perfiles creativos puede guiar prácticas educativas más personalizadas, reconociendo la creatividad como un constructo cognitivo independiente que merece atención en futuras investigaciones. Además, proporciona una base sólida para explorar cómo la creatividad se manifiesta en diferentes contextos y perfiles neurocognitivos, lo que podría informar el diseño de intervenciones educativas más efectivas y equitativas.

En esta Tesis Doctoral, se ha examinado la relación entre la creatividad y las FE en adolescentes, explorando cómo estas capacidades cognitivas interactúan y se afectan mutuamente en diferentes perfiles neurocognitivos. Los hallazgos de nuestra investigación ofrecen una visión integral sobre cómo estas variables se manifiestan en distintos contextos y qué implicaciones tienen para el desarrollo educativo y cognitivo.

Primero, nuestros resultados confirman la importancia de la flexibilidad cognitiva y la memoria de trabajo en la creatividad. Hemos observado que la flexibilidad está estrechamente relacionada con la creatividad verbal, mientras que la relación entre memoria de trabajo y creatividad es más tenue. Este patrón coincide con estudios anteriores que destacan el papel crucial de la flexibilidad en la generación de ideas

creativas (Ardila, 2018; Benedek et al., 2014). La menor correlación entre memoria de trabajo y creatividad podría estar relacionada con el tipo específico de tareas creativas evaluadas y el contexto del estudio.

Al comparar diferentes perfiles neurocognitivos, hemos encontrado variaciones significativas en la creatividad y las FE. Los estudiantes con TDAH demostraron una mayor creatividad verbal en comparación con los estudiantes neurotípicos y los estudiantes con altas capacidades, lo que sugiere que estos estudiantes podrían tener ventajas en tareas divergentes debido a una menor inhibición cognitiva (Hoogman et al., 2020). En contraste, los estudiantes con DI mostraron puntuaciones más bajas en creatividad verbal, lo cual se alinea con estudios que destacan la diversidad en los perfiles cognitivos dentro del espectro neurodivergente (De Caroli y Sagone, 2014).

En cuanto a la creatividad figurativa, los resultados revelaron tendencias diversas. Los estudiantes con dislexia mostraron alta originalidad figurativa, mientras que los estudiantes con TDAH tuvieron puntuaciones más bajas en este ámbito. Este hallazgo está en línea con la literatura que indica déficits en la atención a detalles en estudiantes con TDAH (González-Carpio et al., 2017; Lam y Tong, 2021). Estos resultados destacan la importancia de adaptar las evaluaciones de creatividad a las características específicas de cada perfil neurocognitivo.

El análisis de perfiles latentes (LPA) identificó tres perfiles creativos distintos, con niveles medios de creatividad figural en todos ellos. Aunque estos perfiles no coincidieron completamente con clasificaciones tradicionales, proporcionaron una visión valiosa sobre cómo se distribuyen la creatividad verbal y figural en relación con la inteligencia y las FE. Este hallazgo subraya la necesidad de enfoques más matizados para entender la creatividad (Paek y Runco, 2018; Stamatis y Weisman de Mamani, 2022).

En términos de género, no encontramos diferencias estadísticamente significativas entre niños y niñas en los perfiles creativos. Sin embargo, se observó una tendencia hacia una mayor representación masculina en los perfiles de alta creatividad verbal, lo que se alinea parcialmente con estudios previos que sugieren diferencias de género en creatividad verbal (Taylor y Barbot, 2021). La presencia de un porcentaje significativo de estudiantes con NEAE en el grupo de alta creatividad verbal indica que el contexto y las necesidades específicas también juegan un papel importante en el desarrollo creativo.

Los resultados destacan la importancia de una educación flexible y adaptada que reconozca y aproveche las fortalezas creativas y cognitivas de los estudiantes, independientemente de su perfil neurodivergente. Además, la falta de diferencias significativas en algunas áreas entre perfiles creativos y variables de resultado resalta la complejidad de la relación entre la creatividad, las FE y la inteligencia. Este estudio sugiere que futuras investigaciones deberían centrarse en desentrañar los mecanismos subyacentes que influyen en estas relaciones y cómo pueden informar prácticas educativas más inclusivas y efectivas.

5.2. CONCLUSIONES/CONCLUSIONS

5.2.1. Conclusiones

A modo de cierre de esta Tesis Doctoral, es fundamental sintetizar los principales hallazgos obtenidos a lo largo de los estudios realizados. A través de un enfoque multidimensional que ha explorado la creatividad y las FE en adolescentes, se han alcanzado conclusiones que aportan un conocimiento profundo sobre cómo estos constructos interactúan y se desarrollan en contextos educativos y clínicos. A continuación, se presentan las conclusiones clave derivadas de esta investigación, las cuales subrayan las implicaciones tanto teóricas como prácticas para el desarrollo cognitivo y creativo de los adolescentes.

- La creatividad y las FE muestran una relación estadísticamente significativa, con una relación positiva con la flexibilidad cognitiva y una relación negativa con la inhibición, siendo estas dos FE factores clave en el desarrollo creativo.
- Las FE, como la planificación y la flexibilidad cognitiva, tienden a mejorar a medida que los estudiantes avanzan en los cursos escolares.
- Algunos componentes de la creatividad, especialmente a nivel figurativo, tienden a disminuir a medida que los estudiantes avanzan en los niveles educativos, lo que resalta la necesidad de intervenir para fomentar la creatividad de manera continua.
- Las FE, como la memoria de trabajo y la flexibilidad cognitiva, muestran un valor predictivo sobre la inteligencia, mientras que la creatividad medida como pensamiento divergente no.
- Los componentes creativos y de las FE varían considerablemente entre estudiantes neurotípicos y neurodivergentes, incluyendo aquellos con TDAH,

dislexia, DI y con altas capacidades, revelando distintos puntos fuertes y debilidades.

- El análisis de perfiles creativos reveló tres perfiles distintos de creatividad verbal y figural, desafiando las clasificaciones previas y sugiriendo una mayor diversidad en la expresión creativa entre los adolescentes.
- El tipo de NEAE influyó en los perfiles creativos, con una mayor presencia de SEN en el perfil de alta creatividad verbal.
- El uso de la RV para evaluar las FE ha demostrado ser un entorno ecológicamente válido, ofreciendo una medición dinámica y precisa que puede mejorar las evaluaciones y las intervenciones clínicas.
- Las herramientas de evaluación de la creatividad pueden no ser completamente adecuadas para estudiantes con NEAE, indicando la necesidad de adaptar las pruebas para capturar de manera precisa sus capacidades creativas y ejecutivas.

5.2.2. Conclusions

In conclusion, it is imperative to synthesize the primary findings derived from the studies conducted. Through a multidimensional approach that has explored the interrelationships between creativity and executive functions (EF) in adolescents, conclusions have been reached that provide a comprehensive understanding of how these constructs interact and develop in educational and clinical contexts. The following are the key findings derived from this research, which highlight both theoretical and practical implications for adolescent cognitive and creative development.

- There is a significant relationship between creativity and EF with cognitive flexibility and inhibition being identified as key factors in creative development.
- EF, such as planning and cognitive flexibility, tend to improve as students' progress through the school grades.
- Some components of creativity, particularly at the figural level, tend to decline as students' progress through the educational levels, underscoring the necessity for ongoing intervention to foster creativity.
- EF, such as working memory and cognitive flexibility, have been demonstrated to have predictive value on intelligence. Conversely, creativity, as measured by divergent thinking, does not appear to have a similar predictive relationship.

- The creative and EF components exhibit considerable variation between neurotypical and neurodivergent students, including those with ADHD, dyslexia, DI, and high abilities. This reveals distinct strengths and weaknesses.
- An analysis of creative profiles revealed three distinct profiles of verbal and figural creativity. This challenges previous classifications and suggests greater diversity in creative expression among adolescents.
- The use of virtual reality (VR) to assess EF has been demonstrated to constitute an ecologically valid environment, offering dynamic and precise measurement that can enhance the efficacy of assessments and clinical interventions.
- The suitability of creativity assessment tools for students with special educational needs (SEN) is questionable, indicating the necessity of adapting tests to accurately capture their creative and executive abilities.

5.3. LIMITACIONES Y LÍNEAS FUTURAS

Como cualquier trabajo de investigación, esta Tesis Doctoral presenta varias limitaciones que deben ser consideradas para fortalecer la investigación futura en este campo.

En primer lugar, y de manera específica en el estudio publicado 1 de esta Tesis Doctoral se encuentran limitaciones relacionadas variabilidad en las medidas de creatividad y FE, lo que impide una comparación rigurosa entre estudios. Esta heterogeneidad en las herramientas de medición puede afectar la capacidad para comparar y sintetizar los hallazgos de manera consistente. Además, la tendencia observada hacia resultados positivos en muchos artículos revisados sugiere la posibilidad de un sesgo de publicación en la literatura existente. Este sesgo podría influir en la interpretación de la relación entre creatividad y FE.

Por otro lado, y en relación a los estudios publicados 2 y 3 y al estudio complementario 1, enfrentan limitaciones relacionadas con el tamaño y la composición de la muestra. La muestra puede ser relativamente pequeña para la generalización de los resultados, por ello para obtener conclusiones más robustas, sería beneficioso incluir muestras más grandes y diversas, particularmente en grupos con NEAE.

Además, las medidas de creatividad utilizadas en esta investigación se centraron predominantemente en la creatividad medida como pensamiento divergente, lo que puede no reflejar la totalidad del constructo creativo. La falta de medidas que capturen

concepciones más amplias de la creatividad podría limitar la precisión y objetividad de los resultados obtenidos.

También es importante destacar algunas limitaciones en el uso de la herramienta de RV utilizada para evaluar las FE. A pesar de su validez ecológica, la RV no siempre captura la completa diversidad de situaciones del mundo real, ya que el entorno simulado sigue siendo una representación limitada y controlada. Además, aunque el uso de RV facilita una evaluación más dinámica, los resultados obtenidos pueden variar según la familiaridad del participante con la tecnología o su capacidad para adaptarse al entorno virtual. Esto podría influir en los resultados, especialmente en estudiantes que presentan dificultades que pueden interferir con el uso del equipo de RV.

En este mismo orden de ideas, las pruebas de creatividad y FE suelen estar diseñadas para estudiantes neurotípicos, lo que puede no captar adecuadamente los perfiles cognitivos diversos, especialmente en estudiantes con DI y otras NEAE. Esto sugiere una necesidad de desarrollar y validar instrumentos de evaluación específicos para estas poblaciones.

Teniendo en cuenta las limitaciones expuestas, se plantean una serie de perspectivas futuras. Por un lado, es fundamental la diversificación de las medidas de creatividad, explorando aquellas que no solo aborden el pensamiento divergente, sino también otros aspectos del constructo creativo, como el pensamiento convergente y la creatividad en contextos más amplios. Esto ayudará a capturar una imagen más completa de las habilidades creativas.

Además, realizar investigaciones transculturales y comparativas podría ofrecer perspectivas adicionales sobre cómo los contextos educativos y culturales afectan la relación entre creatividad y FE. Estos estudios ayudarían a identificar prácticas educativas y estrategias de intervención que sean efectivas en diversos contextos.

Abordar estas limitaciones y explorar las líneas futuras de investigación permitirá avanzar en la comprensión de la relación entre creatividad y FE, promoviendo el desarrollo de estrategias más adaptadas e inclusivas para apoyar a todos los estudiantes en su crecimiento académico y personal.

5.4. IMPLICACIONES EDUCATIVAS Y CLÍNICAS

Esta Tesis Doctoral proporciona una visión integral sobre la relación entre FE y creatividad en adolescentes, identificando perfiles creativos diversos y explorando cómo

estos se ven afectados por diferentes perfiles neurocognitivos y factores adicionales. Los hallazgos obtenidos tienen varias implicaciones significativas para la práctica educativa y clínica, y sugieren varias estrategias para maximizar el potencial de los estudiantes y mejorar su desarrollo integral y adaptativo, destacando las siguientes:

1. **Incorporación de estrategias basadas en la creatividad en el aula.** Integrar actividades que fomenten tanto la creatividad verbal como la figurative en el currículo puede ayudar a potenciar las habilidades creativas de todos los estudiantes. Observando que algunos de los componentes de la creatividad empeoran a medida que avanzan los cursos escolares, es importante fomentar el desarrollo de la creatividad Los resultados indican que ciertos perfiles creativos, como aquellos con alta creatividad verbal, también pueden presentar NEAE. Esto sugiere la importancia de diseñar actividades que no solo estimulen la creatividad, sino que también consideren las necesidades individuales. Los programas educativos deben incluir actividades que desafíen a los estudiantes a pensar de manera innovadora y que se adapten a sus capacidades cognitivas y estilos de aprendizaje.
2. **Fomento de la creatividad a lo largo del desarrollo escolar.** Un hallazgo notable es que algunos componentes de la creatividad tienden a disminuir a medida que los estudiantes avanzan en los cursos escolares. Este deterioro potencial subraya la necesidad urgente de fomentar el desarrollo de la creatividad desde una edad temprana y mantener este impulso durante toda la vida escolar. La creatividad es una habilidad esencial para la resolución de problemas, la innovación y el pensamiento crítico. Implementar programas educativos que promuevan la creatividad de manera continua puede ayudar a contrarrestar esta disminución y a preparar a los estudiantes para los desafíos futuros.
3. **Implementación de la RV en el ámbito educativo y clínico.** El uso de RV para evaluar las FE ha permitido un seguimiento más detallado del progreso de los estudiantes. Al utilizar RV, se pueden recopilar datos sobre la interacción de los individuos con diferentes escenarios y tareas, proporcionando una visión dinámica y continua de sus habilidades ejecutivas. Esta capacidad para monitorear y ajustar las intervenciones en tiempo real no solo mejora la efectividad de las estrategias de apoyo, sino que también facilita la identificación temprana de áreas que requieren atención adicional. Además, el uso de RV ofrece la oportunidad de

realizar evaluaciones repetidas de manera menos intrusiva y más motivadora, lo que puede resultar en una mayor adherencia a los programas de intervención y en una evaluación más precisa del impacto de las estrategias implementadas. Este enfoque no solo optimiza los resultados educativos y clínicos, sino que también fortalece la capacidad de personalizar el apoyo según las necesidades cambiantes de los individuos.

4. **Desarrollo de enfoques educativos personalizados.** La identificación de perfiles creativos y las diferencias en FE subraya la necesidad de enfoques educativos adaptativos. Las estrategias pedagógicas deben ser personalizadas para atender a las fortalezas y debilidades específicas de cada estudiante. Por ejemplo, los estudiantes con TDAH que muestran una alta creatividad verbal podrían beneficiarse de métodos de enseñanza que promuevan la exploración divergente y reduzcan las demandas de inhibición cognitiva. Del mismo modo, los estudiantes con DI podrían necesitar adaptaciones en las tareas creativas para facilitar su participación y mejorar su rendimiento.
5. **Diseño de intervenciones clínicas basadas en perfiles neurocognitivos.** En el ámbito clínico, es esencial que las intervenciones se basen en una comprensión detallada del perfil neurocognitivo de cada adolescente. Las terapias y programas de apoyo deben considerar cómo las diferencias en la creatividad y las FE influyen en el rendimiento académico y el bienestar general. Por ejemplo, los adolescentes con dislexia que muestran alta creatividad figurativa podrían beneficiarse de intervenciones que refuercen su capacidad para expresar sus ideas visualmente mientras se apoyan en su fortaleza creativa. Las intervenciones deben ser diseñadas para potenciar las habilidades existentes y abordar áreas específicas de necesidad.
6. **Fomento de la inclusión y adaptación de evaluaciones.** Los resultados subrayan la importancia de adaptar las evaluaciones y los programas educativos para que sean accesibles para estudiantes con diversos perfiles neurocognitivos. La inclusión de adaptaciones en las evaluaciones creativas y cognitivas puede garantizar una evaluación justa y equitativa, permitiendo que todos los estudiantes muestren su verdadero potencial.

En conjunto, esta Tesis Doctoral destaca la necesidad de enfoques educativos y clínicos que reconozcan y apoyen la diversidad en las capacidades creativas y ejecutivas de los

adolescentes. Integrar estos conocimientos en la práctica educativa y en las intervenciones clínicas no solo puede ayudar a mejorar el desarrollo integral de los estudiantes, sino también a crear entornos de aprendizaje más inclusivos y adaptativos que fomenten el potencial creativo y funcional de cada individuo.

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