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Schizotypy and Creativity: Divergent Thinking, Inhibitory Control, and the Spontaneous Flow of Thought

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ABSTRACT

Schizotypy may be associated with heightened creativity, but the exact relationship between schizotypal traits and creative divergent thinking remains unclear. Unlike previous research, which predominantly focused on students, this study ($n = 213$) explored the relationship between schizotypy and divergent thinking in the Alternate Uses Task across a wider age range (from 18 to 78 years, $M = 42.8$). Schizotypy was measured using the shortened O-LIFE scale. To examine moderating factors, inhibitory control was assessed with a Go/NoGo task, and the spontaneous flow of associative thinking was measured with a Forward Flow task. Impulsive Nonconformity was particularly associated with enhanced creativity and originality in divergent thinking, while negative schizotypy had a detrimental effect. Impulsive Nonconformity was especially influential in fostering creativity when combined with reduced inhibitory control or distant associations, aligning with theories that propose creative ideation stems from combining distantly related ideas, because reduced inhibition and distant associations may broaden access to a wider range of information. Conversely, negative schizotypy diminished originality, possibly due to reduced motivation and fluency, coupled with decreased inhibition. These results underscore the complexity of the interaction between inhibition, associative thinking, and creativity, indicating that cognitive resources and processing strategies play critical roles.

Introduction

Psychopathology and creativity

The relationship between mental illness and creativity, the ability to produce something original and meaningful (Runco & Jaeger, 2012), has long intrigued researchers (Fink et al., 2012, 2014). Historically, anecdotal evidence suggests a link between creative genius and mental health disorders, such as depression, bipolar disorder, anxiety disorders, and schizophrenia (Baas et al., 2008, 2016). The list of famous artists (e.g., Vincent van Gogh, Edvard Munch), writers (e.g., Dostojevski, Hemmingway), and scientists (Isaah Newton) who have suffered from mental health problems is long, and biographical studies suggest that artists exhibit a higher lifetime rates of psychopathology than people on average (Feist et al., 2021). For example, in a bibliographic study (Jamison, 1989), the incidence of lifetime psychiatric symptoms of significant British and Irish poets born between 1705 and 1805 was 10–30 times higher compared to the general population. However, a study of 291 of world-famous men from different creativity-related fields suggested that although many of them had unusual personality characteristics and minor neurotic symptoms, severe personality deviations were unduly frequent only in writers and visual artists, and psychotic disorders such as schizophrenia were not exceptionally frequent (Post, 1994). The methodological problem in these kinds of bibliographical studies has been that only a few of them (Andreasen & Canter, 1974) have used matched control groups, creativity has been defined on basis that the person has a particular profession, and the assessment of psychiatric symptoms has not been blinded.

Studies on the relationship between psychotic symptoms and creativity in population samples have provided a complex picture, with evidence supporting both negative and positive associations. On the negative side, research suggests that schizophrenia may be associated with decreased creativity (Wang et al., 2017). Schizophrenia often disrupts cognitive functions and thought processes (McCutcheon et al., 2023), which are critical for creative tasks. For example, impairment of executive processes and theory of mind may be responsible for decreased creativity in schizophrenia (Sampedro, Peña, Ibarretxe-Bilbao, et al., 2020;

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Sampedro, Peña, Ibarretxe-Bilbao, et al., 2020). Similarly, research examining the relationship between psychoticism (a trait related to schizophrenia) and creativity found that the disorganized thought patterns associated with psychoticism negatively affect creative performance (Muhammad et al., 2021).

Meta-analytic reviews further support the claim that schizophrenia may both impair and decrease creativity by demonstrating that mild expressions of schizophrenic symptoms are positively correlated with creativity but severe symptoms, such as in full-blown schizophrenia, have a negative association with creativity (Acar & Sen, 2013; Acar et al., 2018). Genetic factors play a significant role in the relationship between schizophrenia and creativity (Kozbelt et al., 2014; Power et al., 2015). Relatives of individuals with schizophrenia often exhibit higher-than-average creativity, indicating a possible hereditary component (Acar et al., 2018). This genetic link supports the idea that the same genetic factors contributing to schizophrenia might also foster creative abilities in family members, highlighting a complex interplay between genetics and creativity in the context of schizophrenia.

While empirical studies suggest that creative thinking may sometimes be associated with specific forms of mental illness, such as schizophrenia, there is also evidence that engaging in creative activities improves or is positively associated with mental well-being (Bungay & Vella-Burrows, 2013; Jean-Berluche, 2024). This pattern is not necessary contradictory, since biased information processing usually leads to insufficiencies in goal-directed thought and action in context where preserved executive functioning is required, whereas the same biases can lead to advantages in open-ended contexts that call for creativity in thought and action (Khalil & Demarin, 2024).

Schizotypy

Schizotypy refers to a range of personality characteristics and experiences that can be present in the general population to varying degrees, with higher levels of schizotypy being associated with a greater risk for schizophrenia and related disorders (M. T. Nelson et al., 2013). Focusing on schizotypy within subclinical populations offers valuable insights into the mild expression of schizophrenia-related symptoms without the full-blown clinical manifestations of schizophrenia. The present study focused on subclinical schizotypy to obtain a broader understanding of the continuum of psychotic symptoms and their impact on creativity.

Schizotypy is characterized by traits, such as odd or bizarre behavior, strange speech, magical thinking, unusual perceptual experiences, and social anhedonia and withdrawal (M. T. Nelson et al., 2013). The underlying factor structure is usually assumed to consist of dimensions such as positive schizotypy, cognitive disorganization, and negative schizotypy (Venables & Rector, 2000; Vollema & Hoijtink, 2000). The positive dimension includes unusual experiences and magical ideation, such as perceptual aberrations and odd beliefs and fantasies. The negative dimension is manifested as introvertive anhedonia, avoidance of intimacy, and reduced ability to feel physical and social pleasure. The dimension of cognitive disorganization involves attention deficits and distractibility, and problems in decision-making. In addition to these three components, an antisocial dimension in schizotypy, impulsive nonconformity, has been identified (Mason, 1995; Mason & Claridge, 2006). It is characterized by antisocial and impulsive behavior, such as violence, eccentricity, and poor self-control. Unlike other often used scales, such as Schizotypal Personality Questionnaire (SPQ) (Raine, 1991), the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE) (Mason, 1995; Mason & Claridge, 2006) or its shortened version (Mason et al., 2005) includes the antisocial dimension as a separate dimension and it has served as an important tool in studying the four dimensions of schizotypy, that is, Unusual Experiences (positive dimension), Introvertive Anhedonia (negative dimension), Cognitive Disorgnization, and Impulsive Nonconformity (antisocial dimension).

Schizotypy and creativity

Several studies have suggested that the positive dimensions of schizotypy may be related to heightened creativity (Acar & Sen, 2013; Webb et al., 2017). For example, students in visual arts show high scores in the Unusual Experiences (positive) dimension of schizotypy in comparison with the humanities students (O'Reilly et al., 2001) or non-art students (Burch et al., 2006). For self-rated creativity, Unusual Experiences and Impulsive Nonconformity dimensions of the O-LIFE were reported to be positively and significantly related to creativity, whereas the Cognitive Disorganization dimension was found to be negatively related to creativity (Batey & Furnham, 2008). Schuldberg (2001) used compound scores from a variety of self-ratings and other tests of creativity and reported that positive schizotypy was related to increased creativity, whereas negative schitzotypy correlated negatively with creativity.

The present study was interested particularly in the cognitive processes behind the relationship between the

schizotypy dimensions and creativity. Divergent thinking as a cognitive process involves generating multiple, varied ideas or solutions to a problem and it is crucial for creativity (Runco & Acar, 2012). This process encourages breaking away from conventional thought patterns and exploring new possibilities, which is essential for creative, original thinking. Divergent thinking is usually measured with open-ended tasks, of which the most typical is Alternate Uses Task (AUT) (Guilford, 1967), in which the task is to produce uncommon, creative uses for everyday objects (e.g., brick).

The research on the relationship between the dimensions of schizotypy and divergent thinking has revealed variable results. Positive schizotypy/unusual experiences predict divergent thinking as measured with AUT (originality, fluency, flexibility) (Abu-Akel et al., 2020; Webb et al., 2017), with standard fluency task (Tsakanikos & Claridge, 2005), or with a composite score of verbal and figural divergent thinking (Rominger et al., 2017). The Unusual Experiences dimension of schizotypy predicted verbal and figural divergent thinking scores in a study (O'Reilly et al., 2001) which find also a positive correlation between Cognitive Disorganization and figural divergent thinking. Positive relationship between disorganized symptoms (SPQ-disorganized) and verbal and visual divergent thinking was found also by (Carter et al., 2019). However, the association between positive schizotypy (or any other O-LIFE dimension) and divergent thinking has not always been replicated (Carter et al., 2019; Claridge & McDonald, 2009; LeBoutillier et al., 2016). Claridge and Blakey (2009) found that affective temperament but not Unusual Experiences correlated with divergent thinking measures (originality and fluency in pattern meanings interpretation and AUT), although unusual experiences were associated with self-reported engagement in creative activities.

Participants with negative schizotypy may score worse than average in creativity tests. In the studies of Batey and Furnham (2009) and LeBoutillier et al. (2016), negative schizotypy (Introvertive Anhedonia) was associated with impaired performance on divergent thinking tasks, whereas higher creativity was associated with the antisocial dimension of schizotypy (Impulsive Nonconformity). The antisocial schizotypy has been shown to be linked to heightened divergent thinking also in other studies (Burch et al., 2006; Claridge & Blakey, 2009; O'Reilly et al., 2001). Perchtold-Stefan et al. (2022) studied malevolent divergent thinking and found that only the Impulsive Nonconformity dimension of O-LIFE predicted it. In addition, a study on creative thinking (Stanciu & Papasteri, 2018) found that only Impulsive Nonconformity dimension of the O-LIFE dimensions predicted solving insight problems in a convergent thinking task. However, the associations between Impulsive Nonconformity and divergent (or convergent) thinking have not always been observed (Webb et al., 2017).

Cognitive mechanisms of creativity in schizotypy

The overall picture from the studies suggests that positive schizotypy and antisocial schizotypy are the dimensions which most frequently have been associated to improved divergent thinking. One should note, however, that the pattern of results is not coherent as the associations are seldom observed for both positive and antisocial schizotypy in the same study. If positive and antisocial schizotypy increase creative divergent thinking, how can their effects be explained? According to the dual-process model, referred to also as hybrid model, creative thinking is supported by both spontaneous associative and controlled executive processes (Beaty et al., 2014). Creative thinking involves making connections between remote concepts in semantic memory (Beaty & Kenett, 2023). Novel, original ideas are formed by combining remotely associated ideas in new ways. The originality of the ideas can be nowadays objectively operationalized as the semantic distance between the concepts (e.g., between the probe in AUT and participant's response), measured with computational models of semantic memory (Beaty & Johnson, 2021; Beaty et al., 2023). However, mere activation of distant ideas is not sufficient for generating creative ideas. In addition, controlled processing, particularly executive processes (Beaty & Kenett, 2023; Beaty et al., 2014), are needed to direct attention, search memory, and to inhibit common ideas that are closely associated and come easily to mind. Thus, the mechanisms explaining the link between the dimensions of schizotypy and creativity can be searched from the automatic, or spontaneous, associative processes and from the executive processes. Therefore, the present study focused on spontaneous flow of associations and inhibitory control, or both at the same time, as potential moderators between the dimensions of schizotypy and divergent thinking.

The studies on associative processes have shown uncommon semantic processes in schizotypy. In word-association test, individuals with high positive schizotypy, combined with high nonconformity, generated more unusual responses and fewer common responses than comparison individuals (Miller & Chapman, 1983). Healthy persons with a higher magical ideation or positive schizotypy judge more than people on average unrelated words as being more closely related (Mohr et al., 2001) and produce more uncommon responses in

letter fluency (Duchêne et al., 1998), in category fluency tasks (Kiang & Kutas, 2006), and in a figural association task (Rominger et al., 2017). In addition, overinclusive thinking, the inability to preserve conceptual boundaries so that distantly related associations may be incorporated to the same concept, characterize highly schizotypal individuals, and this feature was shown to partly mediate the relationship between schizotypy and creative thinking (Wang et al., 2018). These findings suggest that the unusually "loose" semantic associations in persons with high (positive) schizotypy may enable them to activate distantly related concepts in their semantic networks, facilitating generation of original ideas.

In addition, a candidate executive mechanism for the positive relationship between schizotypy and creativity is diminished inhibitory control, which refers to the reduced ability to filter out irrelevant stimuli or to stop unwanted thoughts, feelings, or actions (Vanova et al., 2023). The role of diminished inhibitory control in enhancing divergent thinking has been shown with experimental manipulations of inhibition (Radel et al., 2015) as well as in correlations between divergent thinking and inhibition, measured for example with Go/NoGo tasks (Khalil et al., 2023). Thus, reduced inhibition may lead to increased access to a broader range of information and associations, which might facilitate creative thinking (Eysenck, 1993; Radel et al., 2015). However, also no relationships or opposing findings, that high levels of creativity are associated with superior inhibitory control, have been reported (for review, see Abraham, 2018, p. 60; Palmiero et al., 2022). These latter findings may be related to the need to inhibit conventional ideas or strong associations entering the mind during creative tasks. However, some of the controversial findings may be explained by methodological differences between the studies, such as the diversity of the measures of inhibition (e,g., Go/NoGo task, Navon task, negative priming, Simon task, Stroop task) and the type of the divergent thinking tasks and their scoring methods (Palmiero et al., 2022).

High overall score of schizotypy (Braunstein-Bercovitz, 2000), and specifically the unusual experiences dimension (N. S. Gray et al., 2002), have been associated with diminished lateral inhibition, an ability to suppress attention to irrelevant stimuli (Braunstein-Bercovitz, 2000). Impairment in Stroop-type color-word inhibition has been associated with high schizotypy (Beech & Claridge, 1987) and with the dimensions of unusual experiences, cognitive disorganization, and impulsive non-conformity (Louise et al., 2015). Rominger et al. (2017) found that high positive schizotypy was associated with increased divergent thinking and low auditory inhibition in a group which had been selected to cover a broad range of positive schizotypy. However, a meta-analysis (Steffens et al., 2018) did not find any relationship between inhibition and positive, negative, or disorganized schizotypy. A more recent study (Vanova et al., 2023) reported that Impulsive Nonconformity predicted inhibition errors in a modified Go/NoGo task requiring responses only to target stimuli and withdrawing responses to nontargets.

Although the role of low inhibition in creativity related to schizotypy has been often speculated, its role has rarely been directly tested with moderation or mediation analyses. Carter et al. (2019) found that inhibition, operationalized as Stroop-interference, moderated the effect of negative schizotypy (SPQ's interpersonal score) on divergent thinking in AUT and pattern meaning test such that low-inhibition participants with high negative schizotypy scored higher than high-inhibition participants with high negative schizotypy. In spite of the moderation, negative schizotypy had a nonsignificant ($p = .089$) negative relationship with divergent thinking, suggesting that negative schizotypy in general did not advance creative thinking. Green and Williams (1999) failed to find any mediation by inhibition (Stroop-negative priming) between the level of schizotypy and divergent thinking. Another study (Wang et al., 2018) divided participants into high and low schizotypy groups on the basis of their total scores on the SPQ. They found that cognitive inhibition partially mediated the relationship between schizotypy and originality of the drawings in extraterrestrials task but not between schizotypy and AUT. In summary, there is some evidence that schizotypy is associated with diminished inhibitory control and that schizotypy's influence on creative thinking may be contributed by inhibitory mechanism, but it remains unclear how inhibition is related to the association between the specific dimensions of schizotypy and creative thinking.

The present study

The present study aimed to explore how the four dimensions of schizotypy are related to creative thinking, as measured with the most typical divergent thinking task, the Alternate Uses task (AUT). Using the dual-process model of creative thinking as a basis, it was studied how spontaneous associative thinking and inhibitory control, a central aspect of executive processing, contribute to the relationship between the dimensions of schizotypy and creativity. Associative thinking can nowadays be studied by making use of distributional semantic models and computational methods for quantifying semantic distance (Beaty & Johnson, 2021; Beaty &

Kenett, 2023). Forward flow (FF) is a recently introduced measure that assesses how much the semantic content of people's thought changes over time (K. Gray et al., 2019; Kenett et al., 2020). FF should not be confused with the more well-known concept of *flow* (Cziksentmihalyi, 2008), which refers to a certain state of mind. In the FF task, participants are presented with a cue word and asked to continue the associative chain by producing the first word that comes to mind for each successive word they produce (e.g., sky-sun-warmth etc.). This makes it possible to study quantitatively how far people travel in a semantic space/network during their spontaneous associative thinking. The present study used in FF the same words as the cues that were used as probes in AUT (but due to counterbalancing, each participant saw each cue only either in FF or AUT task). Because the semantic distance in FF is positively related to creativity and originality of divergent thinking (Beaty et al., 2021; K. Gray et al., 2019), this procedure allowed us to test whether the dimensions of schizotypy differently interact with associative thinking in producing creative or original responses in divergent thinking task (AUT). Based on the literature review presented above, one could hypothesize that at least the relationship between positive schizotypy (Unusual Experiences dimension of O-LIFE) and divergent thinking would be moderated or mediated by the spontaneous flow of associations (FF).

Inhibitory control, a central aspect of executive processing, was measured with the standard Go/NoGo task in which participants are asked to respond to targets and withhold responding to nontargets (Young et al., 2018). Here false alarms (i.e., responses to nontargets) serve as an index of diminished inhibition. On the basis of the view that reduced inhibition might facilitate creative thinking by increasing access to a broader range of information and associations (Radel et al., 2015), it was hypothesized that diminished inhibition will moderate the effects of those dimensions of schizotypy, which are associated to increased creativity in divergent thinking.

The structure of semantic memory contributes to creativity (Beaty et al., 2023; Benedek et al., 2017; S. Mednick, 1962). Here, the structure of semantic memory was taken into account by manipulated the semantic richness of the cue/probe words. Richness was defined as the set-size related to the cue/probe word: a rich semantic cue (RSC) has a greater number of close associations linked to it than a semantically scarce cue (SSC). Therefore, one can expect that fluency (the number of responses) in AUT is higher for RSC words as it should be easy to find related concepts; on the other hand, the SSC words can be expected to produce higher originality, as originality is assumed to result from combining semantically distant concepts; in lack of many close associates the SSC cues drive the participants to travel farther to the semantic space (Beaty et al., 2023). High-quality creative thinking entails the ability to search for novel and remote associations, whereas at the same time the closer associations need to be inhibited. Thus, although reduced inhibition can be expected to facilitate divergent thinking, it may interfere with the search of remotely related ideas especially in trials where the probe has many close associates (i.e., RSC words). Therefore, the possible facilitating effect of reduced inhibition in schizotypy may be restricted to conditions where SSC words serve as probes in AUT. However, the pattern of results may be even more complex, since it is not exactly clear how inhibition and associative processing are related. Reduced capacity for inhibition may play a causal role in generating loose associations because it may allow activation in semantic memory to spread to distant concepts (Radel et al., 2015). Does the possible positive effect of uncommon associative processing in schizotypy depend on inhibitory control such that reduced inhibitory control allows irrelevant associations to access the mind and this leads to "loose" or semantically distant associations, which may facilitate creative thinking? Or are reduced inhibition and uncommon associative thinking different mechanisms that can facilitate creativity independently? The design of the present study allows to test whether reduced inhibition (FAs in Go/NoGo) and distant associations in spontaneous flow of thought (in FF) interact to enhance divergent thinking.

In summary, while the existing literature provides substantial evidence linking schizotypy with enhanced creative abilities, several questions remain open. It is unclear which of the schizotypal dimensions are related to enhanced divergent thinking and the exact nature of the cognitive processes that moderate or mediate these relationships is not fully understood. Previous studies on non-clinical samples have typically used university students or artists as participants (Acar & Sen, 2013). The present study used a non-clinical sample with a wider age range and educational background to test which of the O-LIFE dimensions of schizotypy (Uncommon Experiences, Introvertive Anhehonia, Cognitive Disorganization, Impulsive Nonconformity) are related to increased creativity or originality of divergent thinking in AUT. *Originality* of divergent thinking was operationalized objectively as the semantic distance between the probe and the response (Beaty & Johnson, 2021). Because semantic distance does not take into account the usefulness or appropriateness of the

responses, which are stressed in the traditional definition of creativity (Runco & Jaeger, 2012), *creativity* was operationalized with subjective judgments of blinded raters. Second, it was tested whether reduced inhibition, measured as false alarms in Go/Nogo task, moderates the possible effects of the schizotypal dimensions on divergent thinking. Previous studies have rarely reported direct tests of moderation between the schizotypal dimensions and creative thinking, so the exact nature of these relationships remains underexplored. Third, it was tested whether spontaneous flow of associations moderates the effects of schizotypal dimensions on divergent thinking. Spontaneous flow of associations was measured with the FF method (K. Gray et al., 2019) and it was expected that especially Unusual Experiences would be related to a flow of associations that travels to distant concepts in semantic memory, which would facilitate originality of divergent thinking. In addition, it was expected that scarce semantic cues (SSC) with only a small set of close associates would lead to more distant associations in FF than rich semantic cues (RSC) with a larger set of close associates. Fourth, it was explored whether inhibition and associative thinking are independent or dependent processes facilitating divergent thinking in schizotypy.

Methods

Participants

This study was accomplished online using PsyToolkit (Stoet, 2010, 2017). Two hundred and 30 participants were recruited for the study through the Prolific service (prolific.com). They were paid £3.30 for their participation, which was estimated to last approximately 22 min. Using the filters in Prolific, the invitation to the study was directed to participants whose primary language was English and who resided in UK, USA, Ireland, Australia, Canada, or New Zealand, and who had no dyslexia or neurodiversity, and whose approval rate in Prolific was 98–100%. They had to use a desktop or laptop computer to respond to the study. Thirty-five of them dropped out and 3 were inactive for Prolific's automatically determined 71-min maximum time for completing the study. Prolific automatically replaced those who dropped out or performed the study for too long time with new participants, so 230 participants completed the study. The final number of participants in the statistical analyses was 213 (108 females and 105 males), as six subjects did not pass the control tasks (at least 2/3 wrong; see section Scales and control questions), 9 scored less hits than group mean −3 SD in the Go/NoGo task, one participant gave inadequate responses in the Forward Flow task, and one participant performed the tasks for 15 h but had not been automatically replaced with a new participant. The mean age of the participants was 42.8 years (SD = 14.5), ranging from 18 to 78 years. Education was measured with 9 alternatives which were reduced to 4 categories: 1) elementary school ($n = 60$), 2) high school diploma or vocational/trade school or equivalent ($n = 35$), 3) associate's or bachelor's degree ($n = 76$), and 4) master's degree or doctorate or PhD ($n = 42$). The study was conducted with the understanding and consent of each participant, and in accordance with the Declaration of Helsinki. The study was accepted by the Ethics Committee for Human Sciences at the University of Turku, Finland (approval no. TY/695/06.01.01/2023).

According to power calculations with G*Power (Faul et al., 2007), made before the data collection, the collected sample should be well-positioned to detect with 80% power, at a significance level of .05, smallish to medium-sized effects for 8–10 fixed predictors in regression models (e.g., four traits and their interactions with an additional variable). However, the statistical analyses used linear mixed-effect models which consider both the fixed effects and the random effects (Bates et al., 2015). Therefore, the main limitation of our power calculations was that they did not consider the random effects and thus the procedure gave only a ballpark estimate of the required sample size based on fixed effects. ANOVA and linear mixed-effect models typically yield identical inferential statistics for main effects and interactions in balanced designs with simple random effect structure (Kliegl, 2011).

Tasks

The Forward Flow task (FF) was always the first task, followed by the Alternate Uses Task (AUT) and then by the Go/NoGo task. The scales (see Section 2.2.3) were filled-in in randomized order after these tasks.

Forward flow and alternate uses tasks

Stimuli. Eight words were selected from Beaty et al. (2023, Study 4) for the FF and AUT tasks. According to association norms (University of South Florida Free Association Norms database (D. L. Nelson et al., 2004), 4 of them were semantically scarce cue words (SSC) (*brush, hammer, mirror, umbrella*), which do not have many semantically close, easily accessible words associated with them. Four were semantically rich cue words (RSC) (*barrel, basket, football, pants*) with many semantically close words associated with them. Beaty et al. (2023) had matched the frequency and concreteness between the SSC and RSC words.

For each participant, two SSC and two RSC words served as the cue words in the FF task, and another two SSC and two RSC words as probes in the AUT tasks. The occurrence of the different words in the FF task and AUT was counterbalanced so that all words appeared equally often at the group level in both tasks, but each participant only saw each word in one of the tasks.

Procedure in forward flow (FF). Forward Flow (FF) measured spontaneous flow of associations. Before the FF task began, the participants were given a general written instruction: "For the next task, you'll be shown a word and are asked to write down the next word that follows in your mind from the given word. Then, the task continues so that you are asked to write down the word that follows in your mind from the word you just produced, and so on. Type single words, and do not type proper nouns (such as names, brands, etc.)." When the participant clicked the "continue" button, 10 boxes appeared on the screen, each of which could be filled with a word, with the text above them stating: "Type to the first box the next word that follows in your mind from the word [cue word], and then type to the next box the word that follows in your mind from the word you just produced, and so on." Once a word was typed into each box, the task restarted with another word. Four FF tasks were performed in randomized order, with two tasks starting from an SSC word cue and two with a RSC word cue. Each task was ended when all the 10 boxed were filled (without time limit) and the participant pressed the continue button.

Procedure in alternate uses task (AUT). In the beginning of the AUT tasks, a general written instruction, modified from that of Beaty and Johnson (2021), was given: "For the next 4 tasks, you'll be asked to come up with original and creative uses for an object. The goal is to come up with *creative ideas*, which are ideas that strike people as clever, unusual, interesting, uncommon, humorous, innovative, or different. You can type in as many ideas as you can, but *creative quality is more important than quantity*. It's better to have a few really good ideas than a lot of uncreative ones (e.g., for 'brick,' a response such as 'building a wall' refers to a typical use of brick and therefore it is an uncreative response, so do not produce such common uses). You have 60 s to respond to each object." When the participant had read the instruction and had clicked the "continue" button, 10 boxes appeared on the screen, each of which could be filled with a response, with the text above them stating: "Enter each creative use for [probe word] in separate white line below. After 60 s, the task will change automatically." When 60 s had passed, the boxes disappeared and a new AUT task began. Each participant performed four AUT tasks, two with SSC probes and two with RSC probes in randomized order.

Go/NoGo task

Inhibitory control was measured using the Go/NoGo task. Each trial started with text "Ready" appearing on the center of the screen for a random duration between 700 and 1000 ms, after which it was replaced with the letter "x" or "y" for 100 ms. Participants were instructed to press the spacebar as quickly as possible whenever they saw an "x" letter (= go stimulus) and to withhold from pressing when they saw a "y" letter (= nogo stimulus). The participants were told that they had only 1 s time to respond in each trial, and both speed and accuracy was stressed. The next trial started immediately after the spacebar was pressed, or automatically after 1000 ms if no response was made. Of the letter stimuli, 96 (80%) were Go stimuli ("x") and 24 (20%) were NoGo stimuli ("y"), creating a strong tendency for participants to press the spacebar and make false alarms (FAs; sometimes called also as "commission errors"), that is, pressing the key in response to a NoGo stimulus instead of inhibiting and withholding the response. Multiple FAs to NoGo stimuli indicate impulsivity and weakness in inhibitory control. Thus, consistent with previous relevant literature (Wright et al., 2014), the sum of FAs served as the measure for lack of inhibition.

Scales and control questions

Schizotypy was measured with Oxford – Liverpool Inventory of Feelings and Experiences (O-LIFE) short version (Mason & Claridge, 2006) It consists of 43 statements, and the participants have to responded to each one according to whether it applies to them or not (yes/no). It assessed four features: Unusual Experiences (or positive schizotypy; 12 items, e.g., "Are your thoughts sometimes so strong that you can almost hear them?"), Cognitive Disorganization (11 items, e.g., "Do you often have difficulties in controlling your thoughts?"), Introvertive Anhedonia (negative schizotypy, 10 items, "Are there very few things that you have ever enjoyed doing?"), and Impulsive Nonconformity (antisocial schizotypy, 10 items, e.g., ""Do you often feel the impulse to spend money which you know you can't afford?"). Cronbach's α for the whole scale was 0.87 in the present sample. For subscales, Cronbach's α was 0.81 for Unusual Experiences, 0.80 for Cognitive Disorganization, 0.73 for Introvertive Anhedonia, and 0.62 for Impulsive Nonconformity.

In addition, the participants filled in the 18-item Adult ADHD Self-Report (ASRS) scale (Kessler et al., 2005) and the Autism Spectrum Quotient – short (AQ-short) scale (Hoekstra et al., 2011). The results from the ASRS and AQ-short scales are not reported here, because they were included so that the present sample can serve as a comparison group for neurodivergent participants in future studies.

Among the statements of the scales, three control statements were embedded, to test how carefully and attentively the subjects performed the tasks. For example, to the claim "Did you learn to drive a car when you were only one year old?" the subjects were expected to answer "No." Failure to disagree with two or more similar "nonsense" claims resulted in the subject's data being rejected from the analyses as unreliable.

Scoring the responses in FF and AUT

Before the analyses of the FF and AUT data, the participants' responses were proofread. For FF, each cue was paired with the words produced after it. For AUT, each probe word was paired with each response to it. The SemDis platform (http://semdis.wlu.psu.edu/) (Beaty & Johnson, 2021) was used for computing the semantic distance between all cue/probe-response pairs. SemDis computed the semantic distance in five broad semantic spaces as well as averages calculated across these spaces (see Beaty & Johnson, 2021). The "multiplicative" compositional model option was used to account for responses with multiple words. In addition, the responses were preprocessed using the "remove filler and clean" setting, which removes "stop words" (e.g., the, an, a, to) and punctuation marks that can confound semantic distance computation. For each two SSC and two RSC cue words in FF, the average distance of the responses in relation to the cue (averaged across the five spaces) was taken, and the average of them served as a variable for SSC and RSC conditions.

For each two SSC and two RSC probe word in AUT, the average distance of the responses (averaged across the five spaces) was taken, and the average of them served as a variable for SSC and RSC conditions. However, 9 participants lacked a response to one of the SSC probes and 4 participants lacked a response to one of the RSC probes, while having made response(s) to the other probes. In these cases, before averaging the scores within RSC or SSC conditions, the lacking score was substituted with the whole participant group's minimum score for the probe.[1] In this way, also the failure to give a response to a probe was considered in scoring, rather than removing the participant's whole data or computing the RSC or RSC score only on the basis of responses to one probe. These procedures would have biased the scores upward.

Thus, the resulting FF score indexed how far semantically on average the spontaneous thought of the participants flew from the starting word. The AUT score indexed objectively-measured *originality* of responses, as the semantic distance between the AUT probe and the responses has been shown to correlate primarily with originally (Acar et al., 2023; Beaty & Johnson, 2021; Beaty et al., 2022).

Five independent raters, master-level psychology students, rated the AUT responses for *creativity*. The individual responses to each AUT object were arranged in alphabetic order on separate Excel sheets. The raters were asked to evaluate the responses on scale from 1 (*not at all creative*) to 5 (*very creative*) in relation to the instructions given to the participants: according to the instructions, creative responses are those that are "ideas that strike people as clever, unusual, interesting, uncommon, humorous, innovative, or different." In addition, the appropriateness of the ideas was emphasized, so that creative ideas would be also useful or meaningful in a particular context, whereas uncreative ideas are common uses of the object or inappropriate/non-meaningful/confusing uses that do not make sense. If a participant did not produce any response to one of the SSC or RSC probes, the missing response was scored as 1. The average scores across the 5 raters were taken as the final subjectively-measured creativity score for SSC and RSC conditions. Interrater reliability for creativity ratings was calculated with Intraclass Correlation (ICC) method (model = two way, type = consistency). For SSC and RSC, the ICCs were 0.91 (95% CI [0.89, 0.92]) and ICC = 0.92 (95% CI [0.91, 0.93]), respectively.

Fluency was defined as the number of responses in AUT for SSC and RSC probes. The present study was not interested in fluency *per se*, because the instructions stressed quality rather than the number of responses. Fluency was included as a covariate in the models on AUT variables, because it is known to be a confounding factor in analyses of AUT (Dygert & Jarosz, 2020).

Statistical analyses

The descriptive statistics, correlations, and analyses of simple effects were computed using Jamovi (https://www.jamovi.org) and the linear mixed effect models with the lme4 package (Bates et al., 2015) in R (R Core Team, 2021). The p-values for the models were computed with lmerTest (Kuznetsova et al., 2017) and the figures with sjPlot (Lüdecke, 2024).

First, a basic linear mixed effect model with all four O-LIFE dimensions and their interactions with Set Size

(SSC, RSC) was performed, separately for subjectively-measured creativity and objectively-measured originality in AUT as outcome variables. Set Size was deviation coded so that the fixed ("main") effects of each dimension reflect the effect of each dimension across both levels of Set Size. Education and Fluency served as covariates and random intercept for participants as a random effect. Most of the FF and AUT variables and FA were negatively skewed. Therefore, they as well as the O-LIFE dimensions all were normalized and scaled ($M = 0$, SD = 1) with rank-based Blom's procedure with rcompanion package (Mangiafico, 2023) before entering them into the models.

For studying the moderation effects of FA, first the 3-way interactions (e.g., UnExp x Set Size x FA) for each O-LIFE variable were added to the basic model. This full model stage was needed to rule out the possibility of hidden moderation effects which might not be observed if all the fixed effects are not included in the model. However, inclusion of all fixed effects results in a complex model (21 fixed effects) which has the risk of overfitting. Therefore, bootstrapping of the confidence intervals was used to test for overfitting. Bootstrapping the confidence intervals allows to assess the stability and reliability of the model coefficients, because overfitted models often show a high degree of variability in parameter estimates across different bootstrap samples. 5000 simulations in 5 samples were performed and the CIs were plotted to facilitate comparison of confidence intervals (see Supplemental material, Figures S1-S4). After having observed that the full models produced stable estimates, to simplify the final models, the final moderation models were computed with the four O-LIFE dimension and those of their interactions with the moderator which were detected in the full model at alpha level of 0.05. The models with FF as a moderator were built using the same procedure. Finally, the interaction between FA and FF was explored including the dimension x FA x FF interaction into the models of creativity or originality for those of the dimensions of O-LIFE which showed that either FA, FF, or both moderated the effects of the dimension.

Results

Descriptive statistics

Table 1 presents the descriptive statistics of the scale and task variables, and Table 2 displays the

Table 1. Descriptive statistics ($n = 213$).

			95% CI			
	Mean	SD	Lower	Upper	Min	Max
Unusual Experiences	2.39	2.73	2.02	2.75	0.00	11.00
Cognitive Disorganization	4.14	3.07	3.72	4.55	0.00	11.00
Introvertive Anhedonia	3.36	2.60	3.01	3.71	0.00	10.00
Impulsive Nonconformity	2.38	2.15	2.09	2.65	0.00	8.00
O-LIFE sum	12.04	7.47	11.03	13.05	0.00	38.00
False Alarms (FA)	7.26	4.18	6.70	7.83	0.00	19.00
Forward Flow (FF) SSC	0.87	0.03	0.86	0.87	0.76	0.93
Forward Flow (FF) RSC	0.85	0.05	0.84	0.86	0.70	0.93
AUT Creativity SSC	2.36	0.45	2.30	2.42	1.24	3.60
AUT Creativity RSC	2.48	0.54	2.41	2.55	1.20	3.53
AUT Originality SSC	0.95	0.07	0.94	0.96	0.66	1.07
AUT Originality RSC	0.95	0.07	0.94	0.95	0.68	1.04
AUT Fluency SSC	3.01	1.51	2.81	3.22	1.00	9.00
AUT FluencyRSC	3.46	1.61	3.24	3.67	1.00	10.50[1]

AUT = Alternate Uses Task, SSC = scarce semantic cues, RSC = rich semantic cues.
Forward Flow (FF) was calculated between cue words which were used as the probes in AUT and the responses to each cue. [1]One of the participants produced 10 and 11 responses to the RSC probes; although each AUT task included only 10 boxes for responding, few participants had written more than one response to a single box.

Table 2. Intercorrelations (Spearmans'rho) between age, education, and the O-LIFE dimensions ($n = 213$).

	Age	Education	UnExp	CogDis	IntAnh
Age	—				
Education	−0.218**	—			
UnExp	0.005	0.001	—		
CogDis	−0.095	−0.073	0.466***	—	
IntAnh	0.152*	−0.066	0.233***	0.351***	—
ImpNon	−0.300***	0.082	0.400***	0.342***	0.108

*$p < .05$, **$p < .01$, ***$p < .001$.
FA = false alarms; UnExp = Unusual Experiences; CogDis = Cognitive Disorganization, IntAnh = Introvertive Anhedonia; ImpNon = Impulsive Nonconformity.

intercorrelations (Spearman) between the O-LIFE dimensions and age and education. The semantically scarce cues (SSC) in the FF task elicited more distantly related word responses than rich cues (RSC), $t(212) = 5.11$, $p < .001$, $d = 0.35$. For objectively-measured originality in AUT, the responses to SSC and RSC did not differ from each other, $t(212) = 0.90$, $p = .370$, $d = 0.06$, whereas the subjectively-measured creativity of responses to RSC words was higher than those to SSC words, $t(212) = 4.24$, $p < .001$, $d = 0.29$. In addition, fluency in AUT (i.e., the number of responses) was higher after RSC probes than SSC probes, $t(212) = 7.46$, $p < .001$, $d = 0.51$. Given the short time for responding, only one of the participants was able to produce more than 9 responses to the probes (10 and 11 responses to the RSC probes).

Age correlated negatively with Education and Impulsive Nonconformity and positively with Introvertive Anhedonia (Table 2). The descriptive statistics as a function of education and age are presented in Supplemental materials (Table S1 and S2). Education did not correlate with the O-LIFE dimensions. All the intercorrelations between O-LIFE dimensions were statistically significant, except that between Introvertive Anhedonia and Impulsive Nonconformity. In the linear mixed-effect analyses of AUT outcome variables, Education and Fluency were always used as covariates, because in each model they had significant effects on AUT. Age, on the other hand, did not have any statistically detectable effect in any of the models, so it was not included as a covariate.

FA correlated with Impulsive Nonconformity, $r_s = 0.14$, $p = .049$, but not with the other O-LIFE dimensions, $-0.03 < r_s < 0.06$, $.358 < p < .712$. FF did not correlate with any O-LIFE dimension (for SSC: $0.03 < r_s < 0.08$; $0.25 < p < .57$; for RSC: $-0.09 < r_s < 0.02$; $0.21 < p < .80$).

Models on the four dimensions of O-LIFE and Set Size

First, exploratory linear mixed effect models with Age and its' interactions with O-LIFE dimensions and Set Size as fixed effects were run on subjectively-measured creativity and objectively-measured originality in AUT (Supplemental materials, Table S3). Because Age did not have any statistically significant effects, it was left out from further analyses. The basic linear mixed-effect models (Table 3, Figure 1) with the O-LIFE dimensions and their interactions with Set Size revealed that Unusual Experiences were associated with decreased creativity. High Introvertive Anhedonia was related to decreased originality. In contrast to these negative effects, high Impulsive Nonconformity was associated with increased creativity and originality, and high Cognitive Disorganization was related to increased originality but not to creativity. Set Size had a main effect on creativity, showing that the responses were more creative after semantically rich cue (RSC) than after semantically scarce cue (SSC), but there was no interaction between the O-LIFE dimensions and Set Size. For originality, Set Size had no detectable effects.

False alarms (FAs) as moderators

Building the linear mixed effect models was started with computing full models by adding the FA as moderator to all O-LIFE dimensions and their interactions with Set Size. This resulted in 21 fixed predictors (the covariates included), which may result in overfitting. The confidence intervals in this complex model were bootstrapped (5 samples with 5000 simulations) which allowed to assess the stability and reliability of the model coefficients (see Supplemental material). The confidence intervals did not show a high degree of variability across the different bootstrap samples,

Table 3. The linear mixed effect models with the four dimensions of O-LIFE, set size, and their interactions as predictors ($n = 213$).

	Creativity				Originality			
Predictors	e	95% CI	t	p	b	95% CI	t	p
(Intercept)	−0.24	−0.52–0.03	−1.74	0.082	−0.46	−0.70 – −0.23	−3.88	<0.001***
UnExp	−0.18	−0.33 – −0.03	−2.34	0.020*	−0.08	−0.21–0.05	−1.25	0.211
CogDis	−0.07	−0.21–0.07	−0.96	0.339	0.13	0.01–0.25	2.11	0.035*
IntAnh	−0.02	−0.15–0.11	−0.31	0.760	−0.14	−0.25 – −0.04	−2.61	0.009**
ImpNon	0.23	0.09–0.37	3.26	0.001***	0.14	0.03–0.26	2.41	0.016*
Set size	0.33	0.19–0.46	4.70	<0.001***	0.00	−0.18–0.17	−0.02	0.986
Education	0.10	−0.00–0.20	1.94	0.053	0.19	0.10–0.28	4.25	<0.001***
Fluency	−0.14	−0.25 – −0.03	−2.59	0.010**	−0.23	−0.33 – −0.13	−4.54	<0.001***
UnExp*Set size	−0.06	−0.24–0.12	−0.69	0.490	−0.19	−0.42–0.05	−1.57	0.118
CogDis*Set size	−0.02	−0.19–0.15	−0.25	0.806	0.09	−0.13–0.32	0.83	0.405
IntAnh*Set size	−0.01	−0.16–0.14	−0.17	0.867	−0.06	−0.26–0.13	−0.62	0.537
ImpNon*Set size	0.01	−0.15–0.18	0.14	0.888	−0.01	−0.22–0.21	−0.05	0.960

*$p < .05$, **$p < .01$, ***$p < .001$.

e = β (beta) for standardized regression coefficients and B for the categorical variable Set size and its interactions. FA = false alarms; UnExp = Unusual Experiences; CogDis = Cognitive Disorganization, IntAnh = Introvertive Anhedonia; ImpNon = Impulsive Nonconformity

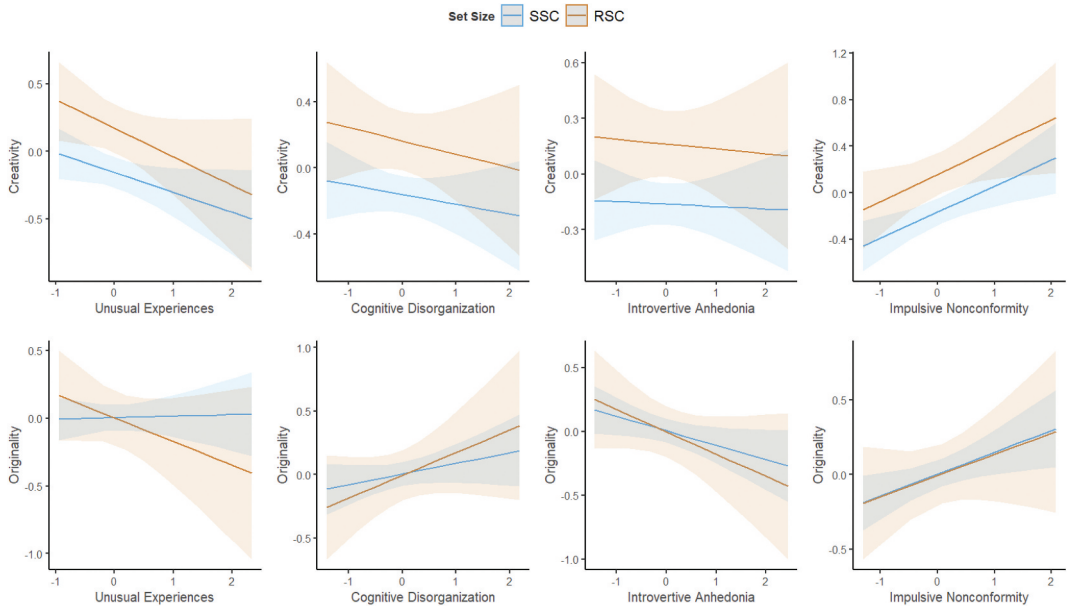

Figure 1. The modeled effects of the O-LIFE dimensions and set size on creativity (upper panel) and originality (lower panel). The shaded areas represent 95% CIs.

Table 4. The linear mixed effect models on the interactions between O-LIFE dimensions and false alarms (Fa)($n = 213$).

	Creativity				Originality			
Predictors	e	95% CI	t	p	b	95% CI	t	p
(Intercept)	−0.25	−0.52–0.02	−1.79	0.074	−0.47	−0.70 – −0.23	−3.91	<0.001***
UnExp	−0.18	−0.33 – −0.03	−2.39	0.017	−0.08	−0.21–0.04	−1.30	0.193
CogDis	−0.07	−0.21–0.07	−0.93	0.352	0.14	0.01–0.26	2.18	0.030*
IntAnh	−0.04	−0.16–0.09	−0.60	0.548	−0.14	−0.25 – −0.03	−2.56	0.011*
ImpNon	0.23	0.10–0.37	3.36	0.001***	0.14	0.02–0.26	2.31	0.021*
FA	−0.12	−0.23 – −0.00	−2.03	0.043	0.06	−0.04–0.16	1.19	0.235
Set size	0.33	0.19–0.46	4.74	<0.001***	−0.01	−0.19–0.16	−0.17	0.866
education	0.10	−0.01–0.20	1.86	0.064	0.19	0.10–0.28	4.27	<0.001***
Fluency	−0.16	−0.26 – −0.05	−2.85	0.005**	−0.23	−0.33 – −0.13	−4.50	<0.001***
ImpNon*FA	0.16	0.04–0.29	2.54	0.012*				
IntAnh*Set size					−0.07	−0.25–0.11	−0.75	0.456
IntAnh*FA					−0.04	−0.14–0.05	−0.88	0.378
Set size*FA					−0.01	−0.19–0.16	−0.15	0.877
IntAnh*Set size*FA					−0.19	−0.37 – −0.01	−2.11	0.035*

*$p < .05$, **$p < .01$, ***$p < .001$.
e = β (beta) for standardized regression coefficients and B for the categorical variable Set size and its interactions. UnExp = Unusual Experiences; CogDis = Cognitive Disorganization, IntAnh = Introvertive Anhedonia; ImpNon = Impulsive Nonconformity; FA = False alarms

suggesting that overfitting was not a problem. Then, the final model (Table 4) was built by including only the interactions from the complex model which were statistically significant ($p < .05$) along with the 4 dimensions of O-LIFE and FA.

The results showed that Impulsive Nonconformity interacted statistically significantly with FA in the model for creativity (Figure 2, upper left panel), suggesting that the more Impulsive Nonconformity and FAs increased, the higher the creativity score. Analysis of simple effects showed no effect of Impulsive Nonconformity at the low level of FA (mean − 1SD), β = 0.07, 95% CI [−0.12, 0.26], $p = .454$, while the effect was highly significant at the mean level of FA, β = 0.23, 95% CI [0.10, 0.37], $p < .001$, and high level of FA (mean +1SD), β = 0.40, 95% CI [0.21, 0.58], $p < .001$.

Introvertive Anhedonia, Set Size, and FAs interacted in the model for originality (Figure 2b). Analysis of simple effects did not detect any effects of Introvertive Anhedonia for originality in the SSC condition (ps > .10). The moderation occurred in the RSC condition, where Introvertive Anhedonia decreased originality at the mean FA level, β = −0.18, 95% CI [−0.32, −0.03], $p = .015$, and at the high FA level (mean +1SD), β = −0.31, 95% CI [−0.51, −0.12], $p = .002$, but not at the low level of FA (mean-1SD), β = −0.04, 95% CI [−0.23, 0.15]. Thus, the higher the Introvertive Anhedonia and FA rate, the lower the originality in response rich semantic cues.

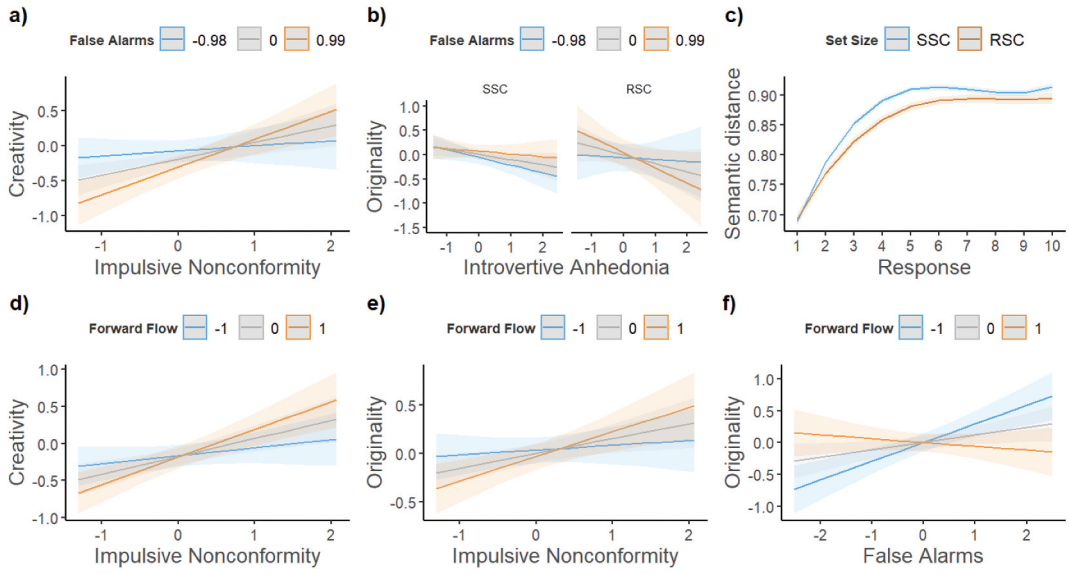

Figure 2. Moderation effects. a) creativity as a function of impulsive nonconformity and false alarms, b) originality as a function of introvertive anhedonia, false alarms, and set size, c) semantic distance between the cue word and 1st −10th response in forward flow task, and the moderation effects of forward flow on d) creativity and e) originality, and f) the interaction between false alarms and forward flow. The shaded areas represent 95% CIs.

Forward flow as a moderator

Figure 2c shows how the spontaneous flow of thought travels to associations that are farther away from the cue when the FF task progresses. Quadratic and cubic polynomial models for the Set Size x Response interaction were tested, and the cubic model explained the data better, $\chi^2(2) = 424.59$, $p < .001$). The responses in the SSC condition reached more distantly related words than those in the RSC condition, B = −0.02, 95% CI [−0.021, − 0.016], $p < .001$. The cubic interaction ($p < .001$) between Set Size and Response (semantic distance = 0.859 + 5.09(Response) − 3.38(Response^2) + 1.32 (Response^3) − 0.02 (Set Size) + 0.02 (Response × Set Size) + 0.60 (Response × Set Size^2) − 0.71 (Response^3 × Set Size) + ϵ) suggests that the first and second responses were relatively closely semantically related to the cue words in both Set Size conditions. The semantic distance increased in responses 3–6, more after SSC cues than after RSC cues, and after that the distance in responses 7–10 did not anymore markedly grow and the difference between responses to SSC and RSC leveled off but did not completely disappear.

The analyses with FF as a moderator were performed similarly to those of FAs. The full model with 21 fixed predictors did not show a high degree of variability in confidence intervals across the different bootstrap samples (see Supplemental material), suggesting that overfitting was not a problem. The final models (Table 5) included as fixed effects the FF scores and their statistically significant interactions ($p < .05$) from the full model in addition to the O-LIFE dimensions and covariates.

Table 5. The linear mixed effect models on the interactions between O-LIFE dimensions and forward flow ($n = 213$).

	Creativity				Originality			
Predictors	e	95% CI	t	p	b	95% CI	t	p
(Intercept)	−0.25	−0.53–0.03	−1.77	0.077	−0.47	−0.71 – −0.24	−3.93	<0.001***
UnExp	−0.18	−0.33 – −0.03	−2.35	0.019*	−0.08	−0.21–0.05	−1.24	0.216
CogDis	−0.08	−0.23–0.06	−1.13	0.258	0.12	−0.00–0.24	1.92	0.055
IntAnh	−0.01	−0.14–0.12	−0.18	0.861	−0.14	−0.25 – −0.03	−2.46	0.014*
ImpNon	0.24	0.10–0.38	3.40	0.001***	0.15	0.03–0.27	2.54	0.011*
FF	−0.01	−0.10–0.08	−0.17	0.864	−0.03	−0.13–0.06	−0.69	0.491
Set size	0.33	0.20–0.47	4.74	<0.001***	−0.01	−0.19–0.17	−0.13	0.899
education	0.10	−0.00–0.20	1.96	0.051	0.19	0.10–0.28	4.29	<0.001***
Fluency	−0.13	−0.24 – −0.02	−2.39	0.017*	−0.22	−0.32 – −0.12	−4.29	<0.001***
ImpNon* FF	0.13	0.03–0.23	2.68	0.008**	0.10	0.00–0.20	2.01	0.045*

*$p < .05$, **$p < .01$, ***$p < .001$.
e = β (beta) for standardized regression coefficients and B for the categorical variable Set size. UnExp = Unusual Experiences; CogDis = Cognitive Disorganization, IntAnh = Introvertive Anhedonia; ImpNon = Impulsive Nonconformity; FF = Forward Flow

For creativity, the only statistically significant interaction/moderation effect of FF was that between Impulsive Nonconformity and Forward Flow (Figure 2d), suggesting that the higher the impulsive nonconformity and the more distantly related words the participants spontaneous flow of associations reached, the higher was the creative quality of their responses. This was further explored with the analysis of simple effects. The effect of Impulsive Nonconformity was not statistically significant at low level of FF (mean − 1SD), β = 0.11, 95% CI [−0.06, 0.27], p = .192, but it was statistically significant at the mean level of FF, β = 0.24, 95% CI [0.10, 0.38], p < .001, and even more significant at the high level of FF, β = 0.37, 95% CI = 0.20, 0.54], p < .001.

For originality, the Impulsive Nonconformity by FF interaction (Figure 2e) was statistically significant. Analyses of simple effects for originality as an outcome variable revealed that there was no statistically significant effect for Impulsive Nonconformity at the low level of FF (mean − 1SD), β = 0.05, 95% CI [−0.10, 0.20], p = .505. The effect of Impulsive Nonconformity was present at the mean level of FF, β = 0.15, 95% CI [0.03, 0.27], p = .012], and high level of FF (mean +1SD), β = 0.25, 95% CI [0.09, 0.41], p = .002.

Interactions between false alarms (FA) and forward flow (FF)

Because both FA and FF moderated the effects of Impulsive Nonconformity on AUT performance in a similar way in separate models, it was explored further how these measures are related. FA did not correlate (Pearson's correlation) with FF for SSC, r = −0.02, p = .772, or with FF for RSC, r = −0.09, p = .176. These findings suggest that FA and FF did not reflect the same cognitive process. Next, the creativity and originality scores in AUT were predicted with models including FA, FF, Set Size, and their interactions as fixed effects and Education and Fluency as covariates. The model on Creativity did not detect any interaction between FA and FF, β = −0.02, SE = 0.05, 95% CI [−0.11, 0.07, t(411) = −0.50, p = .620, or FA, FF, and Set Size, B = 0.09, SE = 0.08, 95% CI [−0.06, 0.24], t(266) = 1.14, p = .257. Next, Impulsive Nonconformity and its 3-way interaction with FA and FF was added to the model on creativity. The 3-way interaction (Impulsive Nonconformity x FA x FF) was not statistically significant, B = 0.03, SE = 0.05, 95% CI [−0.07, 0.13], t(397) = 0.65, p = .519. The interactions between Impulsive Nonconformity and FA, β = 0.18, SE = 0.07, 95% CI [0.05, 0.31], t (207) = 2.74, p = .007, and Impulsive Nonconformity and FF, β = .13, SE = 0.05, 95% CI [0.03, 0.23], t (410) = 2.62, p = .009, were statistically significant.

The model on originality (FA x FF x Set Size) did not detect the 3-way interaction, B = 0.133, SE = 0.093, 95% CI [−0.048, 0.3148], t(333) = 1.431, p = .153, but the FA x FF interaction (Figure 2e) was statistically significant, β = −0.110, SE = 0.049, 95% CI [−0.206, −0.014], t (384) = −2.217, p = .027. Analysis of simple effects revealed that FA was positively related to originality when FF was low (mean − 1SD), β = 0.195, SE = 0.071, 95% CI [0.055, 0.335], t(303) = 2.745, p = .006, and FF was almost significantly negatively related to originally when FA was high (mean +1SD), β = −0.133, SE = 0.071, 95% CI [−0.272, 0.006], t(370) = −1.881, p = .061. Thus, high originality was obtained when the associations in FF were close and inhibitory control was low, or when the associations were distant and inhibitory control was high. When the Impulusive Nonconformity x FA x FF and the Introvertive Anhedonia x FA x FF x Set Size interactions were added to the model, Impulsive Nonconformity x FF, β = 0.10, SE = 0.05, 05% CI [0.004, 0.21], t(366) = 2.00, p = .047, and FA x FF, β = −0.14, SE = 0.05, 95% CI [−0.24, −0.04], t(351) = −2.60, p = .010, interactions remained statistically significant but none of the higher order interactions including the FA, FF, and Impulsive Nonconformity or Introvertive Anhedonia were statistically significant.

Additional exploratory analyses

Surprisingly, none of the O-LIFE dimensions correlated with FF. Therefore, the FF score was computed also with a more typical scoring procedure in which all the responses provided by a participant were combined with each other (Beaty et al., 2021; K. Gray et al., 2019) and the mean distance of the two most distant pairs was used as the measure. This measure for SSC cues correlated significantly with Impulsive Nonconformity (r = 0.17, p < .015) and almost significantly with Unusual Experiences (r = .13, p = .054), but not with the other O-LIFE dimensions. For RSC cues, Impulsive Nonconformity was the only dimension that correlated with the FF measure, r = 0.16, p = .020. These results suggest that especially the participants with high impulsive nonconformity activate during their spontaneous though a larger inner semantic space than participants on average. However, there was no justification for performing any mediation models examining whether spontaneous flow of thought would be a mediator in the path from Impulsive Nonconformity to creativity or originality of divergent thinking, because FF did not directly predict these outcomes in AUT.

An unexpected finding was that Unusual Experiences was negatively related to creativity (but not to originality) in AUT. The previous studies have revealed either a positive relationship (e.g., Abu-Akel et al., 2020) or no relationship (LeBoutillier et al., 2016) between positive schizotypy and divergent thinking, but to our knowledge none of them have reported a negative relationship. Therefore, it was explored whether this negative relationship applies also for Fluency by conducting a linear mixed effects model with the four O-LIFE dimensions and their interactions with Set Size as fixed effects (and Education as a covariate). The fixed effect of Unusual Experiences was not statistically significant, β = −0.07, SE = 0.08, 95% CI [−0.23, 0.09], t(207) = −0.83, p = .409. Of the O-LIFE dimensions, only the effect of Introvertive Anhedonia was statistically significant, β = −0.18, SE = 0.07, 95% CI [−0.32, −0.04], t(207) = −2.56, p = .011, indicating that the higher the introvertive anhedonia, the fewer responses were generated in AUT.

The effect of Unusual Experiences on creativity measures may depend on the level of Introvertive Anhedonia (Nettle, 2006). Therefore, the negative relationship between Unusual Experiences and creativity was further explored by including the Unusual Experiences x Introvertive Anhedonia and Unusual Experiences x Introvertive Anhedonia x Set Size interactions in the model (reported in Section 3.2) on creativity. It revealed an almost statistically significant Unusual Experiences x Introvertive Anhedonia interaction, β =-0.12, SE = 0.07, 95% CI [−0.25, −0.002], t(203) = −1.90, p = .059. Analysis of simple effects revealed that Unusual Experiences combined with low levels of Introvertive Anhedonia was not associated with creativity β = −0.06, SE = 0.10, 95% CI [−0.25, 0.14], p = .583, whereas Unusual Experiences was negatively associated with creativity when it was combined with mean, β = −0.17, SE = 0.08, 95% CI [−0.32, −0.02], p = .023, or high, β = −0.29, SE = 0.10, 95% CI [−0.48, −0.10], p < .003, levels of Introvertive Anhedonia.

The effects of set size (SSC vs RSC) on AUT did not replicate the result that originality is higher for SSC than RSC conditions (Beaty et al., 2023, Experiment 4). However, in our study, the participants had only 1 min to respond to each AUT probe, which resulted in on average 3 responses per probe, whereas in Beaty et al. the time for responding was 2 min, which resulted in on average 6–7 responses. During the longer response period, there is more time to activate distantly related concepts in semantic memory, a phenomenon known as serial order effect (Hass & Beaty, 2018), which interacted with set size in Beaty et al. (Experiment 3). In our study, the number of responses was too low for allowing a genuine serial position effect analysis. However, the set size effect, favoring SSC, should increase as a function of the number of responses in such way the higher the fluency, the higher the probability of producing highly original or creative responses. Therefore, linear mixed effect models were conducted with Set Size, Fluency, and their interaction as fixed effects on the means of the highest originality (i.e., semantic distance) scores and creativity scores of each probe as the dependent variable. The model on originality showed a marginally significant main effect for Set Size favoring SSC, B = −0.16, SE = 0.08, 95% CI [−0.32, 0.01], t(223) = −1.846, p = .066, and a significant effect for Fluency, β = 0.26, SE = 0.05, 95% CI [0.16, 0.36], t(272) = 5.11, p < .001. Most importantly, the Set Size x Fluency interaction was significant, B = −0.27, SE = 0.09, 95% CI [−0.44, −0.10], t(240) = −3.10, p = .002, suggesting that increasing number of responses (i.e., fluency) led to greater originality especially for responses to SSC. Analysis of simple effects confirmed that when fluency was high (mean +1SD), SSC probes were associated with higher originality than RSC probes, B = −0.42, SE = 0.12, 95% CI [−0.65, −0.19], t(230) = −3.53, p < .001. The corresponding model on creativity did not detect the main effect for Set Size, B = 0.12, SE = 0.07, 95% CI [0.02, 0.26], t(226) = 1.66, p = .099, but the effect of Fluency was significant, β = 0.24, SE = 0.05, 95% CI [0.14, 0.35], t(315) = 4.46, p < .001. For creativity, the also Set Size x Fluency interaction was significant, B = −0.18, Se = 0.07, 95% CI [−0.32, −0.03], t(225) = −2.408, p = .017, showing that the more responses the participants generated, the more the originality of responses to SSC probes increased, compared to RSC probes. In spite of that, according to analysis of simple effects, the SSC probes did not result in statistically higher creativity than RSC probes for high level of fluency (mean +1SD), B = −0.06, SE = 0.10, 95% CI [−0.26, 0.14], t(228) = −0.56, p = .577. However, the pattern observed in the main analysis (Section 3.2.), showing that RSC probes were associated with higher creativity than SSC probes, was replicated only when fluency was 1SD lower than the mean, B = .029, SE = 0.10, 95% CI [0.09, 0.50], t(228) = 2.89, p = .004. These results suggest that the lack of the set size effect in the main analyses for originality and the contradictory effect favoring RSC for creativity were due to the relatively few responses given during the short responding time.

Discussion

Previous research using mostly university student samples or artists has linked schizotypy in non-clinical populations with enhanced creative abilities (Acar & Sen, 2013). However, it remains unclear which dimensions of schizotypy are related to increased creativity and which cognitive processes moderate or mediate these relationships. Unlike previous studies,[2] the present study used a non-clinical sample consisting of a wider age range (M = 42.8 years, ranging from 18 to 78) and educational background to test which dimensions of schizotypy (Unusual Experiences, Introvertive Anhedonia, Cognitive Disorganization, and Impulsive Nonconformity) are related to increased subjectively-measured creativity or objectively-measured originality in divergent thinking. Additionally, it was explored whether reduced inhibition, measured as false alarms in the Go/NoGo task, and the spontaneous flow of associations moderate the effects of schizotypal dimensions on divergent thinking.

The present results suggest that only some dimensions of schizotypy, operationalized with O-LIFE subscales, may facilitate creativity or originality in divergent thinking, while others may decrease them. Impulsive Nonconformity and Cognitive Disorganization showed some positive effects, whereas Unusual Experiences (positive schizotypy) and Introvertive Anhedonia (negative schizotypy) exhibited negative effects.

Impulsive Nonconformity (asocial schizotypy) was associated with increased creativity and originality in AUT. This finding aligns with previous studies (Burch et al., 2006; Claridge & Blakey, 2009; O'Reilly et al., 2001). Impulsive Nonconformity involves spontaneous and nonconformist behavior, which can facilitate the breaking of conventional boundaries and norms, crucial for creative idea generation. A novel finding was that the effect of Impulsive Nonconformity on creativity was moderated by the number of false alarms in the Go/NoGo task, suggesting that participants with high Impulsive Nonconformity and low inhibitory control were particularly capable of producing creative responses. This fits Eysenck's (1993) reduced cognitive inhibition theory of creativity and the view that reduced inhibition might facilitate creative thinking by increasing access to a broader range of information (Radel et al., 2015).

In addition, the relationship between Impulsive Nonconformity and creativity and originality of divergent thinking was also moderated by the spontaneous flow of thought. The more distantly the associations of highly impulsive nonconformists flowed from the cue words in the FF task, the more creative and original were the ideas in AUT. This aligns with current theories of associative and creative thinking (Beaty et al., 2014, 2021) and suggests that participants high in Impulsive Nonconformity and loose associations could activate a larger semantic network based on the probes, allowing them to generate original and creative ideas.

The relationship between inhibition, spontaneous associative thinking, and creative thinking seems to be complex. Inhibition (FA) and associative thinking (FF) did not correlate with each other, suggesting that these two phenomena do not have a direct linear relationship. This implies that reduced inhibition does not necessarily lead to distant associations in spontaneous flow of thought. In line with this, creativity of the ideas produced by participants with higher-than-average Impulsive Nonconformity was explained separately by reduced inhibition and remote flow of associations – they both increased creativity of the responses independently. The results were more complex for originality. When inhibition was weakened (FA was high) and associations were close (FF was low), originality was high. Conversely, when inhibition was strong (low FA) and associations were distant (high FF), originality tended to increase (though the effect was only marginally significant). This pattern suggests that high originality can be reached either with reduced inhibition combined with close associations, or with strong inhibition combined with loose associations, but not when inhibition is strong and association are close, or when inhibition is weak and associations are distant. The finding that the combination of strong inhibition and close associations is not optimal for creative thinking fits nicely to the ideas that originality results from combining distantly related ideas (M. T. Mednick et al., 1964) or diminished inhibition (Radel et al., 2015). However, the finding that the combination of weak inhibition and distant associations did not lead to superior originality, but to relatively low originality, is more difficult to explain. In any case, the interaction between inhibition and associations suggests that they may rely on some common resource, for example, attention. Having the working memory filled with both irrelevant stimuli and distant associations may press too much load on attentional processing, interfering with creative idea generation. Thus, originality in creative thinking may be influenced by the balance of cognitive resources and the strategies employed for processing information. This does not, however, explain why a similar interaction was not obtained for creativity in AUT. Clearly, further research is needed on this issue, but the implication of the results for the relationship between Impulsive Nonconformity and creativity and originality seems clear: disinhibition and flow of associations represent two separate moderating mechanisms.

Cognitive Disorganization was another dimension of schizotypy that was related positively to the originality aspect of divergent thinking (see also Carter et al., 2019; LeBoutillier et al., 2014). Cognitive Disorganization relates to difficulties in coherent and focused thought, mirroring disorganized thinking in schizophrenia. Mild forms of Cognitive Disorganization may foster creativity by allowing for looser associations, thereby enhancing making new connections between distant ideas. However, in the present sample neither the distance of associations in spontaneous flow of though nor inhibitory control moderated the relationship between Cognitive Disorganization and originality. The finding that Cognitive Disorganization was not positively associated with creativity suggest that the mere ability to combine semantically distant (i.e., original) ideas by cognitively disorganized persons does not guarantee creative quality, but the combinations must be formed in such way that they represent a meaningful or appropriate new idea, which may be hindered by the thought disorder associated with cognitive disorganization. In the present study, inappropriate or illogical responses were given the lowest creativity score, whereas the originality score obtained with the semantic distance analysis did not consider these aspects in any way.

Introvertive Anhedonia (negative schizotypy) decreased the originality of responses in AUT. This result was expected on the basis of previous research (Batey & Furnham, 2009; LeBoutillier et al., 2016). Interestingly, this effect was moderated by a complex interaction between Introvertive Anhedonia, FA and Set Size. In other words, the effect of Introvertive Anhedonia depended on reduced inhibition (FA) and semantic richness of the probes (Set Size). When the probes were semantically scarce (SSC), Introvertive Anhedonia was not associated with originality. For semantically rich probes (RSC), the effect depended on inhibition. Introvertive Anhedonia was associated with reduced originality in response to RSC probes when inhibition was at low or average level, but not when inhibition was better than average. According to the dual-process theory of creativity (Beaty et al., 2014), original responses can be achieved by accessing semantically distant ideas, which requires inhibition of close associations. In this framework, the negative effect of Introvertive Anhedonia on originally can be explained by inability to inhibit closely associated ideas in the idea generation phase. The SSC probes have a smaller number of close associates and thus the more distantly related ideas can be more easily reached without load on inhibitory processes. Note that in the FF task the SSC cues elicited responses with higher semantic distance than what the RSC cues did, showing how the structure of semantic memory (Beaty et al., 2023; S. Mednick, 1962) influences the spontaneous flow of thought. The inhibitory mechanism may not explain the whole negative effect of Introvertive Anhedonia on originality, because originality was decreased also at the mean level of inhibition. In addition, exploratory analysis of fluency also revealed that Introvertive Anhedonia was related to decreased number of responses in AUT, replicating previous findings on fluency in negative schizotypy (LeBoutillier et al., 2016; Tsakanikos & Claridge, 2005). It may be that that decreased motivational factors and inability to enjoy creative activity (Baas et al., 2016; Schuldberg, 1990) partly explain the decrease of fluency and originality in negative schizotypy.

Unusual Experiences dimension, reflecting a propensity for perceptual anomalies and magical thinking, has been positively associated with divergent thinking scores in AUT in university students (Abu-Akel et al., 2020; Webb et al., 2017), although also lack of such associations has been often reported (Carter et al., 2019; Claridge & Blakey, 2009; Claridge & McDonald, 2009; LeBoutillier et al., 2016). It was expected that if the ability to think in novel and unconventional ways associated with Unusual Experiences would manifest itself as remote associations in the FF task, it could facilitate the generation of unique responses on the AUT. Unexpectedly, Unusual Experiences (positive schizotypy) was negatively associated with the creativity aspects of divergent thinking, and there was not any clear evidence that the spontaneous flow of associations in participants with highly unusual experiences would proceed farther in their semantic memory. In addition, originality and the number of AUT responses (i.e., fluency) were not related to Uncommon Experience. Thus, the results in the present sample do not support the view (Tsakanikos & Claridge, 2005) that higher automatic spreading activation in semantic memory would be a mechanism which could account for the previously reported link between positive schizotypy and creativity.

The unexpected negative relationship between Unusual Experiences and creativity in divergent thinking may be due to the present sample of participants which was more heterogenous than in the typical samples consisting of young adults in this type of studies. Although studies on divergent thinking have revealed mixed effects, it has been well established that persons working in creative professions (artists, poets) score higher than controls in positive schizotypy (Nettle, 2006; Rawlings & Locarnini, 2008). Nettle (2006) notes that creative groups are high in Unusual Experiences but lower than average in Introvertive Anhedonia. In the current study, Introvertive Anhedonia was

negatively related to fluency and originality of divergent thinking. An exploratory analysis provided some evidence suggesting that the effects of Unusual Experiences on the AUT scores may depend on the level of Introvertive Anhedonia. It showed that the negative relationship between Unusual Experiences and creativity was evident in participants with average or high Introvertive Anhedonia, whereas no such relation was observed in participants with low Introvertive Anhedonia. Introvertive Anhedonia correlated positively with age in the present sample. Thus, if the present sample on average had higher Introvertive Anhedonia compared to the typical young adult or artist samples, that might explain the observed negative association between Uncommon Experiences and creativity.

The study was conducted online, which has both benefits and limitations. A benefit was that data could be collected from participants with a wide range of ages from different countries and with different educational backgrounds, rather than limiting the sample to undergraduates in a single university. A limitation in online studies is that the researcher has little control over participants' motivation or attentiveness in performing the tasks. The present study used easy control questions and performance criteria in the Go/NoGo task to eliminate the data of potentially inattentive or unengaged participants. In addition, to keep participants attentive and motivated, the tasks in online studies needed to be relatively short. Therefore, the short version of O-LIFE to measure the schizotypal dimensions was used and the participants were allowed only 1 min to respond to each AUT probe.

The short responding time in AUT may be responsible for some aspects of the results. The results of the main analyses did not replicate the finding that originality of AUT responses, operationalized as semantic distance, is higher for SSC than RSC cues (Beaty et al., 2023). Originality did not depend on the semantic richness of the probe words, and creativity was higher after RSC than SSC probes. Beaty et al. (Experiment 4) used the same SSC and SRC probes as the present study and found higher originality (i.e., semantic distance) after SSC words (they did not report human-made creativity ratings for these stimuli). Nonetheless, their result that participants generated more responses during the AUT when using RSC compared to SSC probes was replicated in the present study, suggesting that greater semantic content benefits ideational fluency. One should note that in the present study, the time for responding to each AUT probe was kept short (1 min), whereas it was the more commonly used 2 min in Beaty et al. (2023), Experiment 4). When the responding time is longer, there is more time to activate distantly related concepts in semantic memory. In AUT responses, this results in serial position effect (Beaty et al., 2023, Experiment 3), which means that idea originality tends to increase over time (Hass & Beaty, 2018). The early responses earn lower creativity ratings than responses generated later in the responding interval, because the commonly known uses for objects dominate in the initial responses. The serial order effect interacts with set size, with the increase of originality over time being larger for SSC than RSC probes (Beaty et al., 2023). Our exploratory analyses showed that the number of responses (i.e., high fluency) was associated with an increase of originality and creativity specifically in AUT responses to SSC probes. Thus, our failure to observe the set size effect for originality was probably due to the short time allowed for idea generation. It remains open whether the relationship between the dimensions of schizotypy and performance in AUT was influenced by the short time for responding, and it would be plausible to try to replicate the results with a longer time for responding. It might also help to explain why the spontaneous flow of thought (FF) did not directly predict the AUT scores.

In conclusion, this study extends our understanding of the complex relationship between schizotypy and creativity. While a trait like Impulsive Nonconformity can foster divergent thinking, it does so under specific conditions, such as when inhibitory control is reduced or when associative thinking is enhanced. On the other hand, negative schizotypy (Introvertive Anhedonia) tends to hinder the originality of creative thinking, particularly when combined with low inhibition and the task requires inhibition of close associates. These findings emphasize that schizotypy's influence on creativity is not uniform and is moderated by cognitive factors such as inhibition and associative flow. Future research should explore these dynamics further, particularly the role of task-specific factors like time constraints and the type of divergent thinking tasks used. Expanding this work to different modalities of creativity beyond verbal tasks will also be critical to fully understanding how schizotypal traits interact with creative processes.

Notes

1. The failure to give a response to a probe was taken in account in scoring, rather than removing the participant's whole data, or computing the RSC or RSC score only based on the response(s) to one probe, which would have overstated the participants' scores. To use these procedures, one would have to assume that the participants did not respond because they intentionally avoided responding or were just trying to get easy money without effort. However, these

participants passed all the attention and activity checks, gave responses to three of the four AUT probes, and discriminated Go vs. NoGo stimuli slightly better (d' = 3.1) than the other participants (d' = 2.6) in the Go/NoGo task (U = 940, p = .094), and. Given the short 1 min time for responding and the instructions stressing the quality rather than the quantity of responses, it seems probable that the participants with the lacking response to one of the probes had too high response criteria for writing down their ideas or they simply were unable to invent anything creative (e.g., one of the participants wrote: "I cannot think of anything creative").

2. Of the cited directly relevant studies examining the relationship between schizotypy and divergent thinking in AUT, only LeBoutillier et al. (2016) tested a non-clinical population sample in which the age distribution was relatively wide (M = 33.4 years, ranging from 16 to 70) and not limited to students.

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No potential conflict of interest was reported by the author(s).

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Data availability statement

The data sets and R-scripts are available at OSF.io. https://osf.io/6kjax/ (anonymous link for reviewers; public link will be presented when the manuscript has been accepted for publication)

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