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Experiences of absorption and smooth performance during flow are linked to different aspects of creative thinking

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ABSTRACT

Flow, an experience of deep immersion and smooth, effortless performance, is frequently linked to creativity. However, its specific relationship with the core cognitive mechanisms of creative ideation remains unclear. This study (n = 400) investigated how the smooth and immersive dimensions of flow relate to divergent thinking, measured using the Alternate Uses Task (AUT), and how they relate to the spontaneous flow of associations, assessed with the Forward Flow task. State flow was measured in relation to experiences during the AUT, in which participants were required to invent creative uses for common objects. The AUT elicited a partial flow state in which the smooth dimension, in particular, was not fully realized. Smooth performance was associated with increased idea productivity but decreased creativity, especially when responding required inhibition of conventional associations to semantically rich probes. Conversely, immersion was positively associated with creativity and semantic distance, suggesting that deep attentional engagement may facilitate access to remote associations and promote creative ideation. The spontaneous flow of associations (FF) predicted originality and creativity in the AUT independently of flow. The results suggest that the state experienced during the generation of creative uses can be considered a partial flow, or microflow, that does not meet all the requirements of full flow, and that the relative intensity of the smooth and immersive components is associated with a trade-off between the quantity and quality of the outputs.

1. Introduction

The concept of *flow* refers to a specific state of consciousness, defined as deep immersion and optimal functioning during an activity (Csíkszentmihályi, 1975, 2014). Flow can occur as a transient experiential state (state flow) or be captured as a trait-like tendency (dispositional flow), and both forms have been linked—albeit inconsistently—with creative performance across various domains, including music, dance, and work. Despite its central theoretical role, empirical research explicitly examining how flow relates to core cognitive mechanisms of creativity—particularly divergent thinking (Guilford, 1967)—remains scarce and inconclusive. Divergent thinking involves generating multiple, varied, and novel ideas or solutions to open-ended problems, such as producing novel uses for common objects.

1.1. Flow and creativity

Flow has been widely associated with creativity since its inception. The concept of flow originates from Csikszentmihalyi's observation that when work on a painting went well, the artist persisted single-mindedly, disregarding hunger, fatigue, and discomfort — yet quickly lost interest in the artistic creation once it was completed (Nakamura & Csikszentmihályi, 2002). Csikszentmihályi believed that it was the subjective experience of creating, rather than external rewards, that motivated the creative activity. Thus, Csikszentmihályi developed the concept of flow to explain why people engage in activities for their own sake, without relying on extrinsic rewards. Csíkszentmihályi (1975, 1990) distinguished several characteristics of the flow experience: (1) challenge-skill balance, (2) merging of action and awareness, (3) clear goals, (4) unambiguous feedback, (5) concentration on the task, (6) sense of control, (7) loss of self-consciousness, (8) time transformation, and (9) autotelic experience. Thus, flow refers to a state of high but subjectively effortless attention, low self–awareness, and a sense of control that may occur during the performance of tasks that are challenging but matched in difficulty to the individual's skill level (De Manzano, 2020).

Flow has been linked to improved performance, especially in sports (Jackson et al., 2001), musical composition (Byrne et al., 2003; MacDonald et al., 2006), and improvisation (Rosen et al., 2024). Although

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flow and creativity have been closely connected from the start, quantitative studies on their relationship tend to be limited (Cseh, 2016; Cseh et al., 2015). As Lavoie and Main (2024) note, prior research on flow and creativity in activities such as painting or music mainly focused on the later stages of the creative process, where ideas have already been generated and are realized through physical activity. The earlier stage, idea generation, has received little attention. Only a few studies have quantitatively examined how flow relates to the quality of creative ideas during tasks that involve divergent thinking – a key cognitive process in the early phase of the creative process. Divergent thinking is assessed with open-ended tasks that have no predefined correct answers (Guilford, 1967). Cseh et al. (2015) found no significant link between flow and visual divergent thinking. On the contrary, the creative quality of ideas in a design task was positively related to flow in a study conducted in virtual reality (Yang et al., 2019). A recent study (Lavoie & Main, 2024, Experiment 1) showed that experiencing flow during an unrelated previous task had a negative carry-over effect on subsequent verbal divergent thinking tasks. However, it remains to be studied how the flow experienced during the divergent thinking task itself relates to performance in that same task.

Understandably, the majority of flow research has focused on well-ordered activities in areas where performance can become automated through practice, where performance can easily be monitored and controlled, and which therefore have clear goals and standards of success (Cseh, 2016; Peifer et al., 2022). Many areas of creativity, particularly creative thinking, do not seem to fit well into the concept of flow because creative ideation requires producing something *novel* and *original* that is appropriate or useful in a specific context (Runco & Jaeger, 2012), which may not be possible using highly routinized processes only. Therefore, one of the aims of the present study was to examine how the flow experienced during divergent thinking, if it is experienced, differs from the self-reported pattern of flow experienced during typical favorite activities.

Flow has been explained by two complementary theoretical perspectives: domain-based and expertise-based models. Domain-based models (Baer, 1998; Baer & Kaufman, 2005; Csikszentmihályi, 1990) emphasize that flow depends on the structural properties of the task domain, such as clarity of goals, immediacy of feedback, and problem definition. Expertise-based models (Csikszentmihályi, 1997; Ericsson, 1996; Sawyer, 2012), in contrast, locate flow primarily in the match between task demands and the individual's level of skill. Applied to divergent thinking tasks such as the Alternate Uses Task (AUT) (Guilford, 1967), the most commonly used divergent thinking task, in which the goal is to suggest unique, new uses for common objects (e.g., a brick), both perspectives predict limited conditions for full flow. From a domain-based viewpoint, AUT provides weak external structure: goals are loosely specified, feedback is absent during performance, and solution criteria are subjective, which should constrain the immersive aspects of flow. From an expertise-based viewpoint, AUT affords little scope for differentiated expertise because it is brief and minimally knowledge-dependent, suggesting that smooth and fluent performance may not reflect challenge–skill balance. Consequently, both models predict that in AUT, flow is more likely to manifest as a partial or *microflow* (Engeser, 2012; Lavoie & Main, 2019; Nakamura & Csikszentmihályi, 2002), which lacks some of the features of deep flow, and has a shorter duration and a lower intensity. It remains to be studied empirically how flow is manifested during divergent thinking tasks such as AUT.

1.2. *Cognitive processes in creative thinking*

According to dual process theories of creativity, the cognitive processes involved in creative ideation require both spontaneous associative and controlled executive processes (Beaty et al., 2014; Beaty & Kenett, 2023; Benedek et al., 2014). Novel, original ideas are formed by combining remotely associated concepts in new ways (Beaty & Kenett, 2023). Access to such remote concepts is supported by associative processes and the structure of semantic memory in the idea-generation phase (Beaty et al., 2023; Mednick, 1962). In addition, controlled executive processes and attentional control (Beaty et al., 2014; Beaty & Kenett, 2023) are needed to search memory to gain access to distant concepts. It is important to inhibit the activation of semantically close concepts and strong associations so that they do not interfere with searching and accessing remote concepts in semantic memory. Thus, a mental state of effortless attention may not be optimal for creative ideation. While deep immersion may be linked to creative thinking by allowing unconventional ideation via activation of remote semantic associations, the effortless attention and spontaneous, fluent progression in creative tasks might hinder the formation of novel ideas. This might be particularly problematic, especially in response to stimuli that have a rich semantic neighborhood (Beaty et al., 2023). Rich semantic cues (RSCs) are such that, according to free association norms (Nelson et al., 2004), they are connected with many strongly related concepts, whereas scarce semantic cues (SSCs) have a more limited number of strong associations and thus they are associated with a less rich semantic neighborhood. Therefore, in responding to RSCs in divergent thinking tasks, many semantically close concepts may be automatically activated, requiring inhibition. The experience of effortless and spontaneous processing during flow might be associated with a failure to inhibit such close concepts, hindering access to more remote concepts that allow novel combinations of ideas to emerge.

1.3. *Creative thinking and components of flow*

Studying separately the immersive aspect and the effortless aspect of flow might give a more nuanced view of the relationship between flow and divergent thinking. The distinction between *Absorption by Activity* (ABA) —a dimension of flow reflecting deep attentional engagement—and *Fluency of Performance* (FP), which reflects the ease and productivity of task execution (Engeser & Rheinberg, 2008; Rheinberg et al., 2003), seems to capture the immersive and effortless aspects. ABA can be measured with statements such as "*I did not notice time passing*" or "*I was totally absorbed in what I am doing*", while FP is reflected in responses to statements such as "*My thoughts ran fluidly and smoothly*" and "*The right thoughts occurred of their own*".

The present study utilizes the distinction between the absorption and effortless aspects of flow to investigate how these specific flow dimensions relate to divergent thinking performance, as measured by the AUT (Guilford, 1967). We hypothesize that the absorption aspect of flow will be positively associated with *creativity* and *originality* in divergent thinking, measured with AUT, as deeper engagement may facilitate unconventional ideation by leading to activation of remote semantic associations. Conversely, we expect that the effortless aspect will be positively related to *productivity* (i.e., fluency, the number of ideas generated) but negatively related to *originality*, suggesting a potential quantity–quality trade-off in creative cognition. It can be further hypothesized that the effortless aspect is negatively related, especially to the originality of the responses to object probes that have a rich semantic neighborhood (RSCs). That is because RSCs require inhibition of strong associations, which may not necessarily occur during spontaneous performance.

Cognitive neuroscience research suggests that both creativity and flow emerge from dynamic interactions between large-scale brain networks, particularly the default mode network (DMN) and frontal executive control systems (Barnett & Vasiu, 2026; Chrysikou, 2019), but in different ways. Creativity is increasingly understood as arising from cooperation between generative processes supported by the DMN—associated with internally directed cognition, memory retrieval, and associative thinking—and evaluative or goal-directed processes supported by executive control regions in lateral prefrontal and parietal cortex (Beaty et al., 2015; Beaty et al., 2018). Rather than operating in strict opposition, these networks and the salience network appear to transiently couple during creative cognition, allowing spontaneous idea generation to be constrained and refined by top-down control processes. Emerging work on the neural basis of flow similarly highlights reconfigurations of DMN–executive control network interactions, with reduced self-referential activity in medial DMN regions and sustained engagement of task-relevant executive control areas supporting focused attention and performance (Barnett & Vasiu, 2026). Within this framework, different experiential qualities of flow may reflect differential network contributions: executive control regions may underpin the highly focused, immersive aspect of flow (APA), whereas reduced DMN self-monitoring and internally generated processing may contribute to the subjective sense of effortlessness (FP) often reported during optimal performance.

To further improve our understanding of creative cognition and flow, we contrast flow with a similar but theoretically different concept: spontaneous flow of thought, measured through the Forward Flow (FF) task (Gray et al., 2019). FF requires the participants to produce the first word that comes to mind from a cue word, and then to continue the chain by producing the next word that comes to mind from the word that was just produced, etc. The semantic distance of the successive word associations is measured, with larger distances indicating less constrained thinking. Based on the associative theory of creativity (Beaty & Kenett, 2023; Mednick, 1962), this measure reflects the associative component of cognition: how distant and unexpected semantic connections an individual accesses during spontaneous thinking processes—a key feature of original ideas (Beaty & Kenett, 2023). Unlike the immersive and focused nature of state flow, FF captures a more loose, spontaneous mental process that may be especially important for originality of creative thinking, which involves combining distantly related ideas in new and innovative ways. Indeed, FF has been shown to predict originality in AUT (Beaty et al., 2021; Gray et al., 2019). Thus, the spontaneous associative thinking process, measured with FF, does not reflect creativity *per se,* as the participants are not instructed to be creative or original, but it is an important component of the thinking process at the idea generation phase that can lead to creative ideas. In the present adaptation of FF, the distance between the cue word and each association following it was measured, so that the score reflects how remote the associations flew from the starting word.

1.4. Research questions and hypotheses

To clarify how flow is manifested in divergent thinking and how it relates to cognitive markers of divergent thinking, the present study focuses on (i) state flow during AUT performance and its components—Absorption by Activity (ABA) and Fluency of Performance (FP) (Engeser & Rheinberg, 2008; Rheinberg et al., 2003)—and (ii) spontaneous associative thought measured by the Forward Flow task (Gray et al., 2019). Divergent thinking performance was assessed with the Alternate Uses Task (AUT; Guilford, 1967) using multiple outcome measures: fluency (productivity, the number of ideas), creativity or creative quality (objective index of the overall creativity quality of ideas, taking into account originality and appropriateness; see 2.4.3), and semantic distance computed objectively on the SemDis platform (Beaty & Johnson, 2021), which we treat as an indicator of originality. Specifically, as original ideas are produced by combining distantly related concepts (Mednick, 1962), semantic distance in AUT was quantified as the semantic distance between the object probe and each generated use (a larger distance indicating more remote responses and originality, Acar et al., 2023; Beaty et al., 2022; Beaty & Johnson, 2021). In addition, flexibility was operationalized objectively as the semantic dispersion among a participant's own AUT responses, using a modified version of the procedure suggested by Grajzel et al. (2023). It was operationalized as the semantic distance (Beaty & Johnson, 2021) of all combinations of the responses a participant provided to a probe. This allows for a more nuanced measure of flexibility, capturing how far apart ideas are from each other within a semantic network, rather than merely counting the number of categories or category switches as in the traditional approach.

The first research question (RQ1) was: Is state flow attainable during divergent thinking (AUT)? This question is exploratory. Flow theory emphasizes prerequisites such as clear goals and immediate, unambiguous feedback (Csikszentmihályi, 1990; Nakamura & Csikszentmihályi, 2002), whereas AUT is open-ended and time-limited, providing limited performance feedback (Guilford, 1967). Thus, it remains an empirical question whether participants experience state flow during AUT, and what the magnitude and profile of that experience are.

The second research question (RQ2) was: Do the ABA and FP components of flow differ in strength during divergent thinking? Divergent thinking requires both associative processes and executive control, including strategic search and inhibition of dominant associations (Beaty et al., 2014; Beaty & Kenett, 2023; Benedek et al., 2014). These demands may allow strong attentional immersion (ABA), while simultaneously reducing the subjective feeling of effortless, smoothly progressing performance (FP), because controlled search can be experienced as effortful. It was expected (H1) that, during AUT, mean FP will be reduced more than ABA, compared with the pattern of dispositional flow during favorite activities.

Third (RQ3), how is global state flow, operationalized as the total mean score of the Flow Scale Short (FFS) (Engeser & Rheinberg, 2008; Rheinberg et al., 2003), related to AUT outcomes, and does semantic cue richness (RSC vs SSC) moderate these relations? We examine whether the global flow experienced during AUT performance relates to (a) fluency (productivity, the number of uses), (b) creativity, (c) semantic distance (i.e., originality), and (d) semantic-dispersion-based flexibility. We further test whether these relations differ for rich semantic cues (RSCs) versus scarce semantic cues (SSCs). RSCs elicit many strong, conventional associations (Nelson et al., 2004; Beaty et al., 2023), potentially increasing the need for inhibitory control to reach remote ideas (Beaty & Kenett, 2023). This makes cue richness a theoretically motivated moderator, especially for originality-related outcomes. It can be hypothesized (H2a) that higher global state flow will be positively associated with AUT productivity (i.e., fluency, the number of responses). In addition (H2b), associations between global state flow and AUT creative quality, semantic distance, and flexibility are expected to be weaker or mixed, because global flow aggregates components (ABA and FP) that may relate to divergent thinking outcomes in different—and potentially opposing—ways (see RQ4). Therefore, our primary predictions are formulated at the component level:

How are ABA and FP differentially related to productivity, creative quality, semantic distance, and flexibility—and are the effects stronger for RSCs or SSCs (RQ4)? Disentangling the immersive (ABA) and effortless/automatic (FP) aspects of flow should clarify whether flow supports quantity versus quality in divergent thinking. ABA may facilitate sustained engagement and deeper exploration of semantic space, whereas FP may reflect reliance on fluent, dominant associations—especially when cues are semantically rich. Therefore, it is hypothesized (H3a) that higher ABA will be positively associated with creativity, semantic distance, and flexibility in AUT. In addition (H3b), higher FP will be positively associated with AUT productivity (i.e., fluency) and (H3c) higher FP will be negatively associated with AUT creative quality, semantic distance, and flexibility, consistent with the idea that subjectively effortless generation of ideas may favor conventional responses over exploration of remote semantic regions. Furthermore (H3d), the predicted negative associations of FP with creative quality, semantic distance, and flexibility will be stronger for RSCs than for SSCs, because RSCs activate stronger dominant associations that must be inhibited to reach more remote ideas (Nelson et al., 2004; Beaty et al., 2023; Beaty & Kenett, 2023). Additionally, the manipulation of set size (SSC vs. RSC) was expected (H3e) to replicate the previous finding that fluency is higher in response to RSCs than to SSCs, whereas semantic distance is higher for SSCs than RSCs (Beaty et al., 2023).

Finally, it was studied (RQ5) whether spontaneous flow of association, measured with the Forward Flow (FF), reflects a separate phenomenon as the "flow" described by Csíkszentmihályi (1975) and whether it predicts AUT outcomes beyond Csíkszentmihályi's flow. Forward Flow (FF) captures spontaneous associative progression and the extent to which an individual reaches remote associations in a self-propagating chain (Gray et al., 2019). Prior work indicates that FF semantic distance predicts originality in AUT (Gray et al., 2019; Beaty et al., 2021). We therefore test whether FF explains unique variance in AUT outcomes beyond global state flow and beyond ABA and FP. Spontaneous associative processing does not require expertise in any specific domain and does not need deep immersion in the task, so it can be expected to be an independent factor contributing to performance in AUT. It was hypothesized (H4) that FF semantic distance would be a positive independent predictor of AUT semantic distance and creative quality; it would remain a statistically significant predictor when entered into the same models with global state flow or with ABA and FP.

2. Methods

2.1. Participants

Four hundred 18–65 years old participants were recruited through the Prolific service (prolific.com). They were paid £4.00 for their participation, which was estimated to last approximately 30 min. The participants were a general population subsample of a larger preregistered project (https://osf.io/7pe4d?mode=&revisionId=&view_only =), which aims to examine the relationship between psychopathology and creativity, with flow experiences as one of the potential mediators. The invitation to the study was directed to participants whose primary language was English and who resided in the UK, USA, Ireland, Australia, Canada, or New Zealand, and who had an approval rate of 98–100% on Prolific and did not have dyslexia. The gender distribution was balanced using Prolific's quota sample procedure. The participants had to use a desktop or laptop computer to respond to the study. Of the 400 participants, 39 voluntarily dropped out, 1 failed the instruction checks, and 3 were inactive for Prolific's automatically determined 87-minute maximum time for completing the study. Prolific automatically replaced those who dropped out or took too long to complete the study with new participants.

The mean age of the participants in the final sample was 39.2 years (SD = 12.1), ranging from 18 to 65 years. Of them, 199 were females and 201 were males. The highest level of education, or the closest education level corresponding to the provided alternatives, was reported according to eight alternatives: No formal education (n = 1), Elementary school (n = 2), High school diploma or equivalent (n = 90), Vocational/Trade school (n = 34), Associate's degree (n = 21), Bachelor's degree (n = 162), Master's degree (n = 75), Doctorate or PhD (n = 15).

The study was conducted with the understanding and conscious consent of each participant following the Declaration of Helsinki. All procedures were performed in compliance with relevant laws and institutional guidelines and have been approved by the Ethics Committee for Human Sciences at the University of Turku, Finland (data 20.05.2025, approval no. TY/866/2025).

2.2. General procedure

The study was conducted online using PsyToolkit (Stoet, 2010, 2017). Before the study began, the participants were warned that the study contains attention checks and that their contribution may be rejected on the basis of failure in too many of them; they were informed that they could withdraw by closing the browser immediately or at any time during the study. In addition, before continuing to the actual study, the participants had to demonstrate that they were humans by solving a CAPTCHA.

After the collection of demographic information, the scales and tasks relevant to the present study were performed in the order: dispositional FFS (see 2.3), Forward Flow (see 2.4.1), AUT (see 2.4.2), and state FSS (see 2.3). As the data was gathered in the context of a larger project, other scales (data of which are not relevant for the present study and will not be reported here) were also filled in the same test session: a scale measuring hypomania preceded the dispositional FFS, and a scale measuring mood followed it. After that, FF and AUT were accomplished. The FSS measuring flow state was filled immediately after performing AUT. Two additional scales were responded to after the state FSS.

2.3. Scales

Flow was measured with Flow Scale Short (FFS) (Engeser & Rheinberg, 2008; Rheinberg et al., 2003). It is publicly available, and it can be adapted for any purpose. The basic FFS consists of 10 items, which are responded to on a 7-point Likert scale. It can be divided to two subscales named "Fluency of Performance'' (FP: items 2, 4, 5, 7, 8, 9; e.g. "*My thoughts/activities run fluidly and smoothly*") and "Absorption by Activity'' (ABA: items 1, 3, 6, 10; e.g., "*I am totally absorbed in what I am doing*"). Additionally, FFS includes three extra questions that measure the perceived importance of the given task; however, these questions were not utilized in the present study.

Two adapted versions of FSS were created for this study: one to measure dispositional flow and another to assess the experienced flow state during the Alternate Uses Task. In the state version, the statements were modified to past tense (e.g., "*My thoughts ran fluidly and smoothly*"), and participants were asked to rate how they felt during the specific tasks they just completed (1 = *not at all*, 2 = *slightly*, 3 = *somewhat*, 4 = *moderately*, 5 = *quite a bit*, 6 = *much*, 7 = *very much*). In the dispositional version, participants were informed that the statements refer to their general experiences when engaged in their favorite activity (e.g., sport, music, work, art, etc.), and they were asked to indicate how often they typically experience each feeling or situation during that activity (1 = *never*, 2 = *rarely*, 3 = *quite rarely*, 4 = *sometimes*, 5 = *quite often*, 6 = *often*, 7 = *always*). The Cronbach's α was 0.84 for the whole FSS assessing flow state after performing the Alternate Uses Task, and 0.85 for the FP and 0.60 for the ABA subscale. For the dispositional FSS, the corresponding values were 0.81, 0.86, and 0.55, for the whole scale, FP, and ABA, respectively.

2.4. Tasks

Two tasks were performed: Forward Flow (FF), measuring the spontaneous flow of associations, and the Alternate Uses Task (AUT). They both had the same 8 stimuli: 4 scarce semantic cues (SSCs), and 4 rich semantic cues (RSCs), which were counterbalanced such that each participant received each stimulus in one of the tasks only. The SSCs were *brush, hammer, mirror, and umbrella,* which do not have many semantically close, easily accessible words associated with them. The RSCs were *barrel, basket, football, and pants,* with many semantically close words associated with them. According to the University of South Florida Free Association Norms database (Beaty et al., 2023; Nelson et al., 2004), the average set size (i.e., the number of associative responses) of the RSCs ($M = 22$, $SD = 2.5$) was greater than that of SSCs ($M = 7.3$, $SD = 0.95$; $t(6) = 11.21$, $p < 0.001$). The frequency and concreteness between the SSC and RSC words were matched (for details, see Beaty et al. 2023). Thus, 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 served as probes in the AUT tasks.

2.4.1. Forward flow (FF)

In Forward Flow, the instruction told the participants that "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 click "continue" and the task continues and 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 the names of brands, people, or fictional characters, etc." The instruction was followed by an instruction check which was visible on the same page: "Based on the text above, what kind of words are you allowed to write down in the next task?" The participant had to select "single words" which was presented among other alternatives (e.g., brand names, people names, proper nouns, fictional characters) to continue to the task. If the alternative "single words" was not selected, the instructions and the instruction check question were repeated. If a participant failed three times, the study ended automatically.

When the instruction check was successfully accomplished, the FF task began with the presentation of a cue word (either SSC or RSC) in the first page, and when the participant had typed a response and clicked "continue", the task continued to the next page where the word the participant had just written was shown and the word that came next to the mind from this word had to be typed. This continued until 10 responses were typed. Each participant completed the task four times, twice starting from an SSC word and twice starting from an RSC word, in a randomized order.

2.4.2. Alternate Uses task (AUT)

Four AUT tasks were performed, two with SSC probes and two with RSC probes, in randomized order. There were 90 s to respond to each probe, after which the probe changed automatically. The instructions were identical to those in Koivisto and Toivanen (2024), stressing creative quality after Beaty and Johnson (2021). The participants were instructed 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)".

2.4.3. Scoring Forward flow (FF) and Alternate Uses task (AUT)

For scoring the semantic associations in FF and the distance of the responses relative to the probe in AUT, automatic, objective scoring was performed with SemDis platform (Beaty & Johnson, 2021). SemDis computed semantic distance in five broad semantic spaces (two Latent Semantic Analysis models: TASA, GloVe; three continuous bag of words CBOW models, see Beaty & Johnson, 2021), as well as averages across these spaces. The semantic distance values can theoretically range from 0 to 2, with higher scores indicating that the response is more distantly associated with the prompt (in practice, the values cluster around 1). 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. The participants typically start their responses to AUT probes with expressions such as "use", "build ", "create", etc. We removed such words from the beginning of the responses, because they may influence the semantic distance score, even though it is evident that in response, for example, to "basket", the expressions "use it as a cat bed" or "make a cat bed" mean the same idea as simply responding with "cat bed". Sometimes participants repeat the probe word in the responses (e.g., "use basket as a cat bed"). Also, the repetition of the probes in the responses was eliminated, because the distance of a word to itself is zero, and we have noted that in the multiplicative compositional model the repetitions of the probe word decrease the semantic distance score.

In scoring FF, participants' every response was paired with the cue word, resulting in 10 pairs per cue. Similarly, in AUT, the responses were paired with the probe. These pairs were submitted to the SemDis platform. For each pair's score, we used the average semantic distance computed across the five semantic spaces. To form the scores to be used in statistical analyses, each participant's semantic distance scores of every cue/probe-response pair were averaged separately for both SSC and RSC.

For FF, the resulting semantic distance score indicates how far into the semantic space the associations travelled from the cue word. The AUT score indexes objectively-measured *originality* of responses, as the semantic distance between the AUT probe and the responses correlates primarily with originality (Acar et al., 2023; Beaty et al., 2022; Beaty & Johnson, 2021).

SemDis platform was also used for computing the *flexibility* of AUT responses, using a modified version of the procedure suggested by Grajzel et al. (2023). Each participant's all responses to each probe were arranged into pairs (response1-response2, response2-response3, response1-response3, etc.), and then the mean semantic distance for each pair was calculated with SemDis across the five semantic spaces. These scores were averaged separately for SSC and RSC conditions. This method indicates the semantic distance between the generated ideas within the semantic network, providing a more nuanced measure of flexibility than the traditional method, which calculates the number of different categories or switches between categories.

Creativity of the AUT responses was calculated with Ocsai (Organisciak et al., 2023). It is a neural network-based large-language model that has been trained and evaluated against a large collection of human-judged AUT responses from previous studies. It has achieved a correlation up to $r = 0.81$ with human raters. It outputs the scores, named originality, for the responses using a scale from 1 to 5. However, because examination of the studies which have been used to train Ocsai showed that human rates have judged the *creativity* of the responses in many of the studies (Organisciak et al., 2023), we call its score in the present study as *Creativity*, to differentiate it from the type of purely semantically based originality (i.e., semantic distance) calculated by SemDis, which cannot take into account the appropriateness of the responses, a central aspect of creativity along with originality (Runco & Jaeger, 2012). To validate that Ocsai measured predominantly creativity, three human raters, blinded to the Ocsai score, scored the creativity of the AUT responses on the scale from 1 (*uncreative, usual response, or nonsense response without any appropriateness*) to 5 (*highly creative response*; i.e., original and appropriate), taking into account the standard definition according to which creativity refers to ideas that are both original and appropriate in specific context (Runco & Jaeger, 2012). Interrater reliability (ICC, model="twoway", type="consistency", unit = "average") was 0.81 for SSC and 0.86 for RSC, and 0.89 for combined SSC and RSC scores, indicating good agreement. The human-rated creativity scores and the scores of Ocsai correlated strongly with each other at the level of individual's mean AUT scores: $r = 0.86$ for SSC, $r = 0.86$ for RSC, and $r = 0.90$ for the combined SSC and RSC total score. The human creativity scores correlated more weakly with the corresponding semantic distance scores produced by SemDis: $r = 0.40$ for SSC, $r = 0.42$ for RSC, and $r = 0.52$ for the combined SSC and RSC total score. Thus, Ocsai measured the creativity of the AUT responses, whereas SemDis measured the originality of the responses in the sense of how semantically distant the responses were from the probe. Inspite of using human judges for validation, our creativity scores were based purely on the scores derived from Ocsai.

Fluency in AUT was the mean number of responses to probes, calculated separately for the two SSC probes and the two RSC probes. The individual creativity, semantic distance, and flexibility scores were calculated such that first the average of participant's responses (or response pairs in flexibility) to each probe was calculated. Then, from these values, the average of the responses to the two SSC stimuli and the average of the responses to the two RSC were calculated, resulting in one individual SSC score and one individual RSC score.

In summary, the outcome variables were *fluency* in AUT, *creativity* in AUT, *semantic distance* in AUT (indexing originality), *flexibility* in AUT, and semantic distance in FF.

2.5. Statistical analyses

Descriptive statistics, correlations, and simple effects analyses were computed using Jamovi 4.4.11 (The jamovi project, 2024) and the linear mixed-effect models with R (R Core Team, 2021), using lme4 (Bates et al., 2015) and lmertest (Kuznetsova et al., 2017) packages. The models were visualized with sjPlot package (Lüdecke, 2024).

The categorical variable Set Size (scarce vs. rich semantic cues) was simple coded, so the "main" effects and interactions in linear mixed-effect models can be interpreted similarly to, for example, standard analyses of variance. All other variables were continuous. The continuous variables (FSS scales, FF, and AUT variables) were normalized and standardized (M = 0, SD = 1) with Blom's procedure (Mangiafico, 2023) before entering them into the linear mixed-effect models. This ensured the normality of residuals. Collinearity of fixed effects was checked with the performance package in R, and it was not a problem in any of the models (VIFs < 3).

The models were conducted in two stages. In the first stage, only the summary scores of FSS, Set Size, and their interactions were used as fixed effects; in the second stage, the subscales of FFS (FP, ABA), Set Size (SSC, RSC), and their interactions served as fixed effects. Age and education served as covariates in all models. Additionally, Fluency was a covariate in all models on the AUT variables (except the models on Fluency itself) because it is known to be a confounding factor in AUT analyses (Dygert & Jarosz, 2020).

In addition, the models on AUT outcome variables were also run with the global dispositional flow as a covariate when the total FFS was the outcome variable, and then the fit of the models with and without the dispositional flow as a covariate was compared with R's anova() function. The model with total dispositional flow as a covariate showed significantly better fit than the model without it, only for the model on fluency, $\chi^2 = 13.94$, $p < 0.001$. Therefore, the results of the model with the total dispositional flow as an additional covariate are reported in the results section. Correspondingly, the models on AUT variables with FP and APA as predictors were run with (a) the global dispositional flow as a covariate and (b) with the dispositional FP and ABA as covariates. The dispositional flow influenced the model fits only in the models of fluency. The model with global dispositional flow (FFS) as a covariate showed the best fit in the models on fluency, $\chi2 = 14.23$, $p < 0.001$, and its results are reported in the results section.

3. Results

The data and R scripts can be accessed on OSF.io: https://osf.io/cvmkz/?view_only = 1911e6c3596e49f39b6a949bde40ba77.

3.1. Descriptive statistics and correlations

Table 1 presents the descriptive statistics for age, education, and flow variables, as well as their intercorrelations. Age and education did not correlate with any of the variables, while all the flow variables correlated with each other. The correlation between dispositional flow score and state flow score was relatively weak ($r = 0.35$), suggesting that they partially overlap but represent different phenomena.

Fig. 1A shows how the mean scores of dispositional FSS and state FSS were distributed (RQ1). The mean scores of dispositional FSS ($M = 4.9$) and state FFS ($M = 4.4$) (Fig. 1A) align with the typical mean scores, which range between 4 and 5 in various populations (Rheinberg et al., 2003). Although the scales are not directly comparable in their response alternatives (dispositional FSS: 1 = *never*, 7 = *always*; state FSS: 1 = *not at all*, 7 = *very much*), it is useful to compare the response patterns

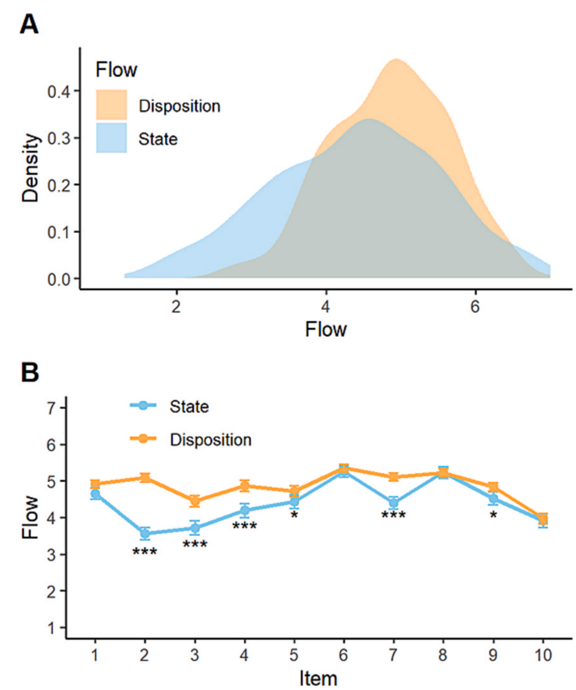

Fig. 1. The upper panel(A) shows the density plot of the dispositional and state flow scores, and the lower panel (b) presents the dispositional and state flow scores for each item. *Note.* Bonferroni-corrected *p*-values: $*p < 0.05$, $**p < 0.01$. $***p < 0.001$. The error bars in B represent *95% CIs*. Items 1, 3, 6, and 10 belong to the Absorption by Activity (ABA) subscale, items 2, 4, 5, 7, 8, and 9 to the Fluency of Performance (FP) subscale.

Table 1
Intercorrelations between background variables and flow variables, and descriptive statistics.

	Age	Education	Disp.Flow	DF-FP	DF-ABA	State Flow	SF-FP	SF-ABA
Age	—							
Education	−0.044	—						
Disp.Flow	0.079	0.099*	—					
DF-FP	0.040	0.162	0.920***	—				
DF-ABA	0.071	−0.045	0.705***	0.394***	—			
Flow State	−0.063	0.108	0.347***	0.352***	0.198***	—		
SF-FP	−0.085	0.158	0.319***	0.364***	0.103*	0.935***	—	
SF-ABA	−0.009	−0.027	0.270***	0.210***	0.284***	0.796***	0.543***	—
Mean	39.20	5.33	4.85	4.97	4.67	4.39	4.39	4.39
SD	12.10	1.57	0.81	1.02	0.86	1.14	1.34	1.19
95% CI lower	38.10	5.18	4.77	4.87	4.59	4.28	4.26	4.27
95% CI higher	40.40	5.49	4.93	5.07	4.76	4.50	4.52	4.50

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Disp. Flow = Dispositional Flow, DF-FP = Dispositional Flow of Performance, DF-ABA = Dispositional Absorption by Activity, Flow S. = State Flow, SF-FP = State Flow of Performance, SF-ABA = State Flow Absorption by Activity.

between the scales to figure out how state flow during AUT differs from the reported typical flows during favorite activities (RQ1, RQ2). A Flow Type (dispositional vs. state) × Subscale (FP vs. ABA) repeated measures analysis of variance suggested that the dispositional flow scores were higher than those of state flow, $F(1399) = 58.95$, $p < 0.001$, $\eta_p^2 = 0.13$. FP scores were higher than ABA scores, $F(1399) = 11.28$, $p < 0.001$, $\eta_p^2 = 0.03$, and the Type × Subscale interaction, $F(1399) = 20.35$, $p < 0.001$, $\eta_p^2 = 0.05$, suggested that specifically the FP scores were lower in the state flow than the dispositional flow (RQ2).

To clarify in more detail how FP and ABA differed between the subscales, we studied (RQ1, RQ2) at the item-level how the reported state flow, experienced during AUT performance, differed from the disposition to enter flow state during favorite activities. Fig. 1B shows how the patterns of flow differed between the scales (exact statistics can be found in Supplementary Materials, Table S1). Of the fluency of performance (FP) subscale scores, ratings of item 2 (*My thoughts ran fluidly and smoothly*) were lower in the state scale than in the dispositional scale, with a large effect size. Similarly, ratings of item 4 (*I had no difficulty concentrating*) and item 7 (*The right thoughts occurred of their own accord*) were lower in the state scale than in the dispositional scale, with small-to moderate effect sizes. In addition, the scores in item 5 (*My mind was completely clear*) and item 9 (*I felt that I have everything under control*) were smaller in the state than the dispositional scale, with very small effect sizes. There was no statistically significant difference in item 8 (*I knew what I had to do each step of the way*).

Of the items in the absorption (ABA) subscale (RQ2), only item 3 (*I did not notice time passing*) received lower ratings in the state scale than in the dispositional one, with small-to-moderate effect size, which is understandable due to the 90 sec time constraint in AUT. The ratings in the other ABA items (item 1: *I felt just the right amount of challenge*, item 6: *I was totally absorbed in what I am doing*, and item 10: *I was completely lost in thought*) did not differ between the dispositional and state flow scales. Thus, the pattern of flow differed between the scales, supporting the hypothesis (H1) that it is mostly the fluency of the performance aspect of flow that differs between state flow (during AUT) and dispositional flow.

The descriptive statistics for the Forward Flow variables and AUT variables are presented in Table 2.

Table 2
Descriptive Statistics for the outcome variables.

	N	*Mean*	*SD*	95% CI *Lower*	*Upper*	*Min*	*Max*
Forward Flow	400	0.86	0.04	0.86	0.86	0.49	0.93
Forward Flow SSC	400	0.87	0.04	0.86	0.87	0.40	0.94
Forward Flow RSC	400	0.85	0.05	0.84	0.85	0.59	0.95
Fluency	397	4.15	1.78	3.98	4.33	1.00	12.50
Fluency SSC	397	3.98	1.91	3.97	4.17	1	14
Fluency RSC	400	4.31	1.90	4.12	4.50	1	11
Creativity	397	2.31	0.55	2.25	2.36	1.00	3.90
Creativity SSC	397	2.24	0.59	2.18	2.30	1.00	3.80
Creativity. RSC	400	2.37	0.59	2.31	2.43	1.00	4.00
Semantic Distance	397	0.95	0.05	0.95	0.96	0.67	1.04
Sem. Dist. SSC	397	0.96	0.05	0.96	0.97	0.77	1.05
Sem.Dist. RSC	400	0.95	0.06	0.94	0.95	0.57	1.04
Flexibility	380	0.96	0.05	0.96	0.97	0.68	1.14
Flexibility SSC	383	0.97	0.06	0.96	0.97	0.71	1.27
Flexibility RSC	393	0.96	0.07	0.95	0.96	0.50	1.24

Note. SSC = scarce semantic cue, RSC = rich semantic cue.
The N varies because some of the participants did not produce any responses to the SSCs in AUT, and because the calculation of flexibility requires at least 2 responses to the same probe. In Forward Flow, Semantic Distance, and Flexibility, the values can range from 0 to 2, with larger values indexing grater semantic distance between the cue/probe and the response, or between the responses in Flexibility; for Creativity the scale ranged from 1 (not creative) to 5 (highly creative); Fluency refers to the number of responses per AUT probe.

3.2. Global flow as predictor

Only the statistically significant effects related to flow or Forward Flow (FF), and Set Size are reported here. Full linear mixed-effect models are presented in the Supplementary Materials (Tables S2-S5). In the first set of analyses, the global scores from the Flow Short Scale (FSS) were used as predictors without separating the subscales (RQ3).

Fluency in Alternate Uses Task (AUT): State flow significantly increased the number of responses generated (consistent with H2a), $\beta = 0.18$, $SE = 0.05$, *95% CI* [0.08, 0.27], $t = 3.70$, $p < 0.001$. Additionally (H3e), more responses were produced in response to rich semantic cues compared to scarce semantic cues, $B = 0.20$, SE = 0.04, *95% CI* [0.12, 0.27], t = 5.36, $p < 0.001$. Semantic distance of the associations in FF was not a significant predictor of fluency (RQ5).

Creativity in AUT: Responses to RSCs were more creative than those to SSCs, $B = 0.27$, $SE = 0.04$, *95% CI* [0.20, 0.35], $t = 6.84$, $p < 0.001$. There was also significant interaction between state flow and Set Size, $B = 0.08$, $SE = 0.04$, *95% CI* [0.01, 0.16], $t = 2.20$, $p = 0.028$, indicating that high flow was associated with decreased creativity in response to SSCs compared to RSCs (Fig. 2). This finding partly supports our H2a that flow may relate to divergent thinking outcomes in potentially opposing ways (increasing fluency but decreasing or having no effect on creativity). Furthermore, the more remote the associations traveled in the FF task, the higher the creativity of the ideas in AUT, $\beta = 0.11$, $SE = 0.03$, *95% CI* [0.06, 0.17], $t = 3.86$, $p < 0.001$. This suggests that, as expected (RQ5, H4), the flow of associations independently contributed to creativity, beyond the effects of state flow.

Semantic Distance in AUT: As expected (H3e), responses to scarce semantic cues (SSCs) were more distantly related to the probe words than responses to rich semantic cues (RSCs), $B = -0.21$, $SE = 0.06$, *95% CI* [-0.33, −0.10], $t = -3.56$, $p < 0.001$. Additionally, state flow was positively associated with semantic distance, $\beta = 0.08$, $SE = 0.04$, *95% CI* [0.00, 0.16], $t = 2.07$, $p = 0.039$, meaning that higher flow scores corresponded with generating ideas that were semantically more distant from the probe (i.e., they were more original). This finding did not support our hypothesis H2b that global flow would be associated with decreased semantic distance or no effect on semantic distance.

Flexibility in AUT: Flexibility—measured by how semantically different the responses were from each other—was not statistically significantly related to global state flow (RQ3, H2b), distance of associations in Forward Flow (RQ5, H4), or to semantic richness of the probes.

In summary, flow state was linked to increased productivity of ideas (i.e., fluency in AUT) but to decreased creative quality of responses to probes with scarce semantic neighborhoods. High state flow was associated with semantically remote ideas relative to the probe. Next,

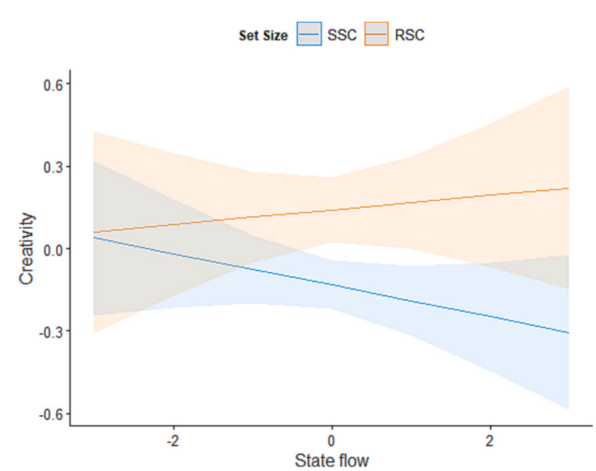

Fig. 2. The modelled effects of state flow and set size on creativity. *Note.* The shaded areas represent *95% CIs*. All the values are standardized.

separating the subscales of Flow Short Scale — FP and ABA — may give a more detailed picture of the relationship between flow and creative thinking (RQ4).

3.3. Flow Scale Short subscales as predictors

The full linear mixed-effect models are presented in Supplementary Materials (Tables S6-S9).

The model on *fluency* in AUT (i.e., the number of ideas; Fig. 3, 1st row) showed that more responses were produced to rich semantic cues (RSCs) than to scarce semantic cues (SSC), $\beta = 0.19$, $SE = 0.04$, *95% CI* [0.12 – 0.27], $t = 5.34$, $p < 0.001$ (H3e). As hypothesized (H3b), fluency of performance (FP) was positively linked to the number of responses, $\beta = 0.22$, $SE = 0.06$, *95% CI* [0.11 – 0.33], $t = 3.88$, $p < 0.001$.

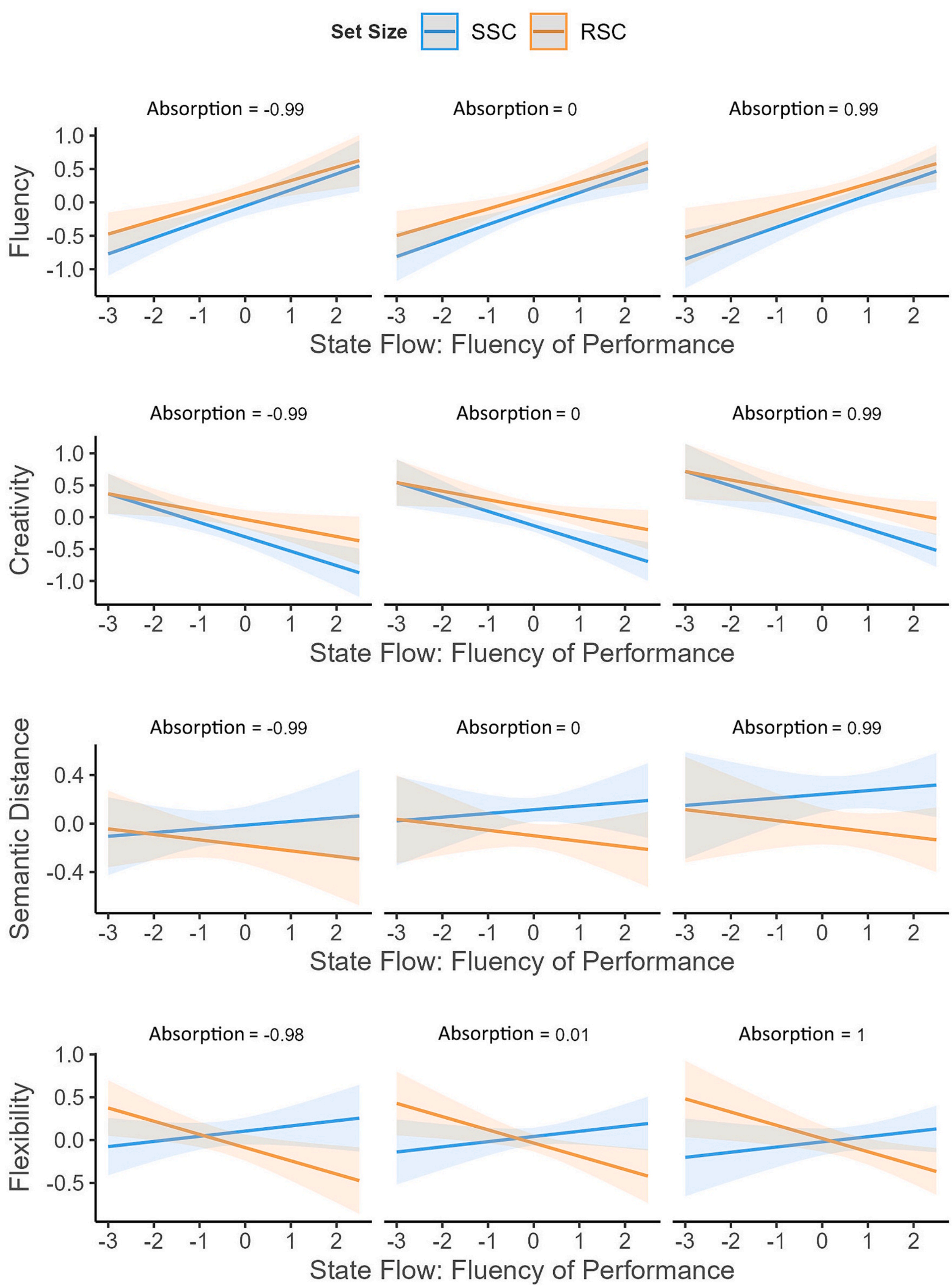

Fig. 3. The modelled effects of Fluency of Performance, Absorption by Activity, and set size on the outcomes in the Alternate Uses Task. *Note.* The shaded areas represent *95% Cis*. All the values are standardized.

The *Creativity* of the ideas in AUT (Fig. 3, 2nd row) was higher in response to rich semantic cues (RSCs) than to scarce semantic cues (SSCs), $B = 0.27$, $SE = 0.04$, *95% CI* [0.19 – 0.35], $t = 6.82$, $p < 0.001$, and the ideas were more creative, the farther into the semantic network the associations travelled in the Feed Forward (FF) task (RQ5, H4), $\beta = 0.11$, $SE = 0.03$, *95% CI* [0.06 – 0.17], $t = 3.91$, $p < 0.001$. Absorption was positively linked to creativity, $\beta = 0.18$, $SE = 0.05$, 95% CI [0.07 – 0.28], $t = 3.28$, $p = 0.001$ (H3a), whereas the fluency of performance tended to be linked to decreased creativity (H3c), $\beta = -0.18$, $SE = 0.05$, *95% CI* [-0.29 – -0.07], $t = -3{,}28$, $p = 0.001$, particularly in response to SSCs, $\beta = 0.09$, $SE = 0.05$, *95% CI* [0.00 – 0.18], $t = 1.98$, $p = 0.049$. Thus, although there was a negative association of FP with creative quality (H3c), the hypothesized association was not stronger for RSCs than for SSCs (H3d).

Semantic distance of the ideas, relative to the AUT probes (Fig. 3, 3rd row), was higher following scarce semantic cues (SSCs) than rich semantic cues (RSCs), $B = -0.21$, $SE = 0.06$, *95% CI* [-0.33 – -0.10], $t = -3.56$, $p < 0.001$ (H3e). In addition, absorption (ABA) was linked to increased semantic distance, $\beta = 0.10$, $SE = 0.05$, *95% CI* [0.01 – 0.20], $t = 2.20$, $p = 0.028$, as expected (H3a).

In the model on *flexibility* in AUT, the smooth and effortless aspect of flow (FP) interacted with Set Size (Fig. 3, bottom row) in such way that the higher the FP, the more the flexibility of the ideas generated to rich semantic cues (RSCs) decreased relative to those generated in response to scarce semantic cues (SSCs), $B = -0.21$, $SE = 0.08$, *95% CI* [-0.37 – -0.06], $t = -2.76$, $p = 0.006$ (RQ4, H3b).

4. Discussion

The present study examined how flow relates to divergent thinking by studying how flow and its smooth component (FP) and immersive component (ABA) are realized during divergent thinking task (AUT) (RQ1–RQ2), how global state flow is related to AUT outcomes (RQ3), the differential roles of the FP and ABA components of flow in divergent thinking (RQ4), and spontaneous associative progression measured by Forward Flow (RQ5). Across these analyses, a coherent pattern emerged that aligns with hybrid models of creativity emphasizing the interplay between associative and controlled processes (Beaty et al., 2014; Benedek et al., 2012; Benedek et al., 2014), as well as with expertise–based and domain–specific models of flow (Csikszentmihályi, 1997; Sawyer, 2012).

4.1. Flow during AUT: Evidence for a partial flow state

The state flow scores in the present study, reflecting experiences during divergent thinking, correspond with those in previous studies, measured during more routinized activities (Laakasuo et al., 2022; Palomäki et al., 2021; Rheinberg et al., 2003). The pattern of the state flow summary scores was slightly different than that of the corresponding scores of dispositional flow, reported in relation to participants' favorite activities (Fig. 1A)(RG1). This pattern is somewhat surprising because, in creative tasks such as the Alternate Uses Task (AUT), the prerequisites of flow — such as clear goals and unambiguous feedback —are not as evident as in areas like sports or music, where performance can be based on highly routinized skills (Cseh, 2016).

The comparison of the components as well as the item–level comparisons between state flow during AUT and dispositional flow during favorite activities (RQ2) revealed a dissociation between the two core components of flow. Consistent with H1, FP items were markedly lower during AUT than during favorite activities, including the sense that thoughts ran smoothly, occurred of their own accord, or required little effort. In contrast, state ABA items remained largely intact, with participants reporting skill-challenge balance, deep immersion and focused attention comparable to dispositional flow, except for time distortion—an expected consequence of the strict 90–second time limit for responding. The participants were aware of the time limit and thus monitored the time.

This pattern suggests that AUT elicits a partial flow state: attentional absorption is relatively preserved, but the subjective sense of effortless performance is diminished. This aligns with expertise–based models of flow, which propose that effortless performance arises when individuals possess automatized skills that allow them to meet task demands without effort (Csikszentmihályi, 1997; Ericsson, 1996). However, AUT is a domain–general task for which participants lack specialized expertise (Nakamura & Csikszentmihályi, 2002). Participants can become absorbed (ABA), but cannot experience full smoothness and effortlessness (FP). The flow during AUT can be considered as microflow, a state elicited within simple tasks that are relatively short in duration and have lessened intensity (Engeser, 2012; Lavoie & Main, 2019; Nakamura and Csikszentmihályi, 2002).

4.2. Global state flow and divergent thinking outcomes

Global state flow, indexed by the total score of FSS, was positively associated with fluency (H2a), indicating that participants who experienced more flow generated more ideas. However, consistent with H2b, global flow showed mixed or cue–dependent associations with creative quality, semantic distance, and flexibility. Flow was associated with increased semantic distance overall, but reduced creative quality for SSCs, and it was not reliably related to flexibility.

Thus, flow during AUT reflects an energized and absorbed state that increases idea production but does not provide the domain-specific scaffolding or automatized expertise required for high-quality creativity. Flow boosted fluency across cue types, but its effect on creativity depended on the semantic richness of the probe: flow enhanced creativity when rich associative structures were available, but reduced creativity when cues were semantically sparse. Although this pattern was relatively weak, it aligns with expertise-based models, which emphasize that fluency in flow depends on automatized skills, and with domain-specific models, which argue that creative flow emerges most readily within structured knowledge networks, in the present case, within semantically rich networks. These mixed effects support the idea that global flow aggregates components (ABA and FP) that may relate to divergent thinking outcomes in opposing ways, motivating the component–level analyses (RQ4).

4.3. Differential roles of FP and ABA in divergent thinking

When the smooth component (FP) and immersive component (ABA) were entered simultaneously into the models (RQ4), their effects diverged sharply, supporting the component–specific hypotheses. Absorption was positively associated with creativity and semantic distance (H3a), consistent with the idea that attentional immersion facilitates deeper exploration of semantic space, resulting in higher creative quality and more original ideas. ABA did not increase fluency, indicating that, unlike FP, absorption supports quality, not quantity.

Effortless and smooth performance (FP) was positively associated with fluency (H3b), but negatively associated with creative quality (H3c), and with reduced flexibility for RSCs (FP × Set Size interaction). This pattern aligns with the hybrid theory of creativity: smooth performance may reflect reliance on dominant associations, especially when probes activate rich semantic neighborhoods (Beaty et al., 2023). Contrary to H3d, the negative effects of FP on creative quality were not stronger for RSCs than SSCs, although FP did reduce flexibility more strongly for RSCs.

Together, these results indicate that FP reflects an energized but shallow aspect of flow, increasing productivity but reducing creative depth, whereas ABA reflects a deeper, domain-general attentional state that supports originality. This pattern aligns with expertise-based models of flow (Csikszentmihályi, 1997; Ericsson, 1996; Sawyer, 2012), which propose that FP depends on automatized skills; when such expertise is absent—as in AUT—flow may amplify easily accessible associations at the expense of deeper exploration. In contrast, ABA, reflecting attentional absorption, predicted higher creativity and greater semantic distance, consistent with domain-specific models (Baer, 1998; Baer & Kaufman, 2005; Csikszentmihályi, 1990), suggesting that flow supports creativity primarily when the task affords meaningful associative structure. The differences between RSCs and SSCs further highlight the importance of domain structure. RSCs provide richer associative networks, functioning as "micro-domains" that support both absorption and creative elaboration. SSCs, by contrast, offer sparse associative environments in which flow—particularly FP—may reinforce superficial processing and reduce creative quality. This domain-sensitivity mirrors Csikszentmihályi's systems model of creativity, which emphasizes that creative performance depends on the interaction between the individual and the structure of the domain (Csikszentmihályi, 1990, 2014). Together, all the findings indicate that AUT elicits a partial flow state: FP energizes idea generation but may hinder creative quality in domain-poor contexts, whereas ABA supports deeper associative processing that enhances originality.

4.4. Forward flow as an independent predictor of originality (RQ5, H4)

Spontaneous flow of association, measured with the Forward Flow (FF), predicted creative quality and semantic distance independently of global flow and the FP/ABA components (H4). This supports the view that spontaneous associative progression captures a distinct mechanism of creativity and originality (Gray et al., 2019; Beaty et al., 2021). It reflects a separate phenomenon as the "flow" described by Csíkszentmihályi (1975). The fact that FF remained a significant predictor, even when FP and ABA were included in the same statistical models, suggests that associative progression and flow-related attentional states contribute independently to divergent thinking. While the absorption aspect of flow was associated with activation of remote concepts, reflecting a focused state of mind and relying on controlled search through the semantic network, the associative progression in semantic networks reflected more spontaneous activation of concepts, without any aim to search for distant concepts.

4.5. Creativity and semantic distance

Further insights into the cognitive processes in divergent thinking arise when comparing semantic distance and creative quality in AUT. While both are indicators of originality, they capture different aspects. Creativity was computed using a neural network (Ocsai) trained on large datasets of human creativity ratings (Organisciak et al., 2023), thereby incorporating not only novelty but also elements of appropriateness and cleverness – key elements of creativity (Runco & Jaeger, 2012). This was also confirmed by the high correlation between the scores of Ocsai and the creativity ratings of three humans. In contrast, semantic distance in AUT reflects the remoteness of ideas from the probe object in semantic space, and it does not consider their contextual appropriateness. Our findings revealed that responses to semantically rich probes received higher creativity scores than responses to scarce semantic probes, consistent with Koivisto & Toivanen (2024), who also found similar patterns in human judgments of creativity. However, semantic distance was greater for responses to semantically scarce than rich cues, highlighting that remoteness in semantic space does not necessarily translate into perceived creativity.

This divergence suggests that while scarce semantic cues may prompt semantically distant associations, these associations may lack the contextual relevance or appropriateness that humans consider when evaluating creativity. Cues with rich semantic neighborhoods, despite offering more conventional associations, may better support the generation of ideas that are simultaneously novel and appropriate—a hallmark of creative ideas. In any case, performance in the Forward Flow task predicted creativity, as expected (H4): the farther into the semantic network the associations travelled, the more creative the ideas in AUT. These results support hybrid or dual process theories that attribute an important role to associative processes in creativity. However, the creativity of ideas depends not just on how far associations travel in semantic space, but also on the perceived utility and cleverness of the ideas.

4.6. Limitations and strengths

A limitation of this study is that only correlational relationships between flow and other measures were analyzed, so causal effects cannot be established. However, the effect of task difficulty (skill-challenge balance) has been experimentally shown to influence the experience of flow in inverted U shape (Larche, & Dixon, 2020; Lu et al., 2025), Therefore, it may be plausible to assume that the performance level during AUT influenced how much flow was experienced. The real challenge for further studies remains to show the opposite causal direction by manipulating the experience of flow and measuring its effect on performance. For example, although the ability to generate many AUT responses may increase the experience of flow, does the mere experience of flow influence the number of responses a participant produces? Another limitation is the low internal consistency of the absorption (ABA) subscale of the FSS. However, the internal consistencies of the whole FSS scale and the fluency of performance (FP) subscale were good. Given that Cronbach's α depends on the number of items, and ABA consisted of only four items, the α-value of 0.60 may be considered acceptable. In general, the factor structure of the FSS has shown inconsistency across different studies and languages (Laakasuo et al., 2022; Rheinberg et al., 2003). Nonetheless, the original FSS subscales (Rheinberg et al., 2003) were reliably related to results supporting most of the hypotheses derived from dual-process theories of creativity.

Here, flow state was considered as a continuous variable, which can be separated into the absorption and fluency components, and it was assumed that individuals can be high in one of the components and low in the other. This view can be challenged by arguing that flow should be defined as a discrete on/off variable so that a specific threshold must be exceeded for an individual to truly be in a flow state (Abuhamdeh, 2020). Even if one were to accept this argument, we believe that the present study sheds light on the relationship between flow and creative ideation through the roles of the two components in the relationship. In the present sample, the global state flow, operationalized as the total FSS score, was associated with increased productivity (i.e., fluency in AUT), increased semantic distance, and decreased creativity in response to semantically scarce probes. However, these effects were weaker than the effects observed when the data were analyzed via the immersive and smoothness components; the componential analyses showed a more nuanced picture of the contribution of the underlying processes.

A limitation is also the generalizability of the results, because only one task (AUT) measuring divergent thinking was used. In addition, AUT can be administered with different instructions. The present instruction stressed creative quality over quantity (i.e., fluency). A *meta*-analysis (Acar et al., 2020) suggests that such instruction leads to enhanced creativity of the responses without influencing fluency. It is, however, possible that the quality instruction influenced how flow was realized during AUT. It may have encouraged an effortful cognitive processing style and therefore exaggerated the absorption component of flow (ABA), and correspondingly reduced the feeling of smooth performance (FP). In contrast, asking participants simply to produce as many uses as they can for the AUT probes might have encouraged less controlled generation of ideas and correspondingly induced a stronger feeling of smooth and effortless performance at the cost of absorption. Such a processing style might have produced a similar, but more exaggerated fluency – quality trade-off as was observed in the present study.

One of the strengths of the present study is that the automatic scoring methods of AUT (Ocsai and SemDis) and Forward Flow (SemDis) were objective in the sense that they are not dependent on the specific sample of participants or on the sample of human raters of the creativity or originality of the responses. The scoring procedures can be easily replicated. The scores will be directly comparable with those of further studies using the same methods. Another strength in relation to typical lab studies is the relatively large and diverse sample of participants (n = 400) with different demographic backgrounds and ages. This was possible because the study was conducted online. Online studies have their own weaknesses, particularly related to the motivation and attention of the participants, which were accounted for here with easy control tasks and by keeping the tasks relatively short. Generally, empirical studies (Peer et al., 2017; Prissé & Jorrat, 2022) show that results obtained in laboratory conditions can be reliably replicated with carefully designed online studies.

4.7. Conclusions and implications

Taken together, the results highlight the importance of distinguishing among the subcomponents of flow state and their complex, sometimes contradictory, roles in the creative ideation process. The findings emphasize that flow is not a single, uniform construct in the context of creative thinking. It can be considered a partial flow or a microflow that does not meet all the requirements of a full or deep flow. Although the study does not permit direct causal inferences, the findings suggest that fostering immersive focus (i.e., absorption) may support creative ideation in real-life situations—such as work, study, or everyday activities—where tasks are relatively short and not overly complex, and where individuals lack the expertise that would otherwise enable smooth and effortless processing. Although the causal effect of skill-challenge balance on experience of flow has been well documented (e.g., in video games, Larche & Dixon 2020), further studies should investigate whether the immersive and smooth flow components can be experimentally manipulated to test their true causal influences on creative thinking. In addition, the generalizability of the results to AUT under different instruction conditions and to different types of creative thinking tasks requires further consideration.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used ChatGPT4 in order to edit and improve the readability of the text. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

CRediT authorship contribution statement

Mika Koivisto: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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.

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Appendix A. Supplementary Tables

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2026.104060.

Data availability

The manuscript contains a link to data in OSF.io

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