What inspires us? An experimental analysis of the semantic meaning of irrelevant information in creative ideation

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Abstract

Past research showed that apparently irrelevant information for a creative task at hand can lead to higher creative performance, especially in open-minded individuals. Through two diverse experimental procedures, the present work investigated which type of irrelevance information can inspire (i.e., increase) the creative performance during a divergent thinking (DT) task and how open-minded individuals can be inspired by this kind of information. In Experiment 1, the attentional processing of information that was either apparently relevant or irrelevant for the execution of a verbal DT task was assessed by means of an eye-tracking methodology. In Experiment 2, creative performance was explored through a verbal priming paradigm, which forcedly introduced apparently irrelevant information during the DT task. In both experiments, the level of irrelevance was operationalized in terms of semantic distance between the different kind of information. Results from both experiments highlighted the role of the semantic meaning of the irrelevant information as one of the main determinants, along with Openness, of inspiration (i.e., enhancement) of the creative performance.

Keywords: inspiration, creativity, attention, semantic distance, divergent thinking, originality, statistical infrequency, Openness

Introduction

Describing his creative process, David Bowie stated: "*I'll take articles out of newspapers, poems that I've written, pieces of other people's books, and put them all into this little warehouse, this container of information, and then hit the random button and it will randomize everything*". Like Bowie, writers, artists, scientists, and other creators usually emphasize the importance of inspiration in the creative process. Inspiration can be defined as the process occurring when individuals perceive something that stimulates them to act creatively (Harding, 1948). Considering creativity as a context-embedded phenomenon requiring potential originality and effectiveness (Corazza, 2016; Corazza & Lubart, 2021; Runco & Jaeger, 2012), the function of inspiration in the creative process is to motivate the actualization of an idea in the form of a truly original and effective product (Thrash, 2021).

Theoretically, inspiration has been conceptualized as a paradoxical state including both passivity and activity, which includes the concepts of transcendence (the gain of awareness of new possibilities), evocation (the receptivity to be inspired by something in particular) and approach motivation (the need to bring a new idea into fruition; Thrash & Elliot, 2003). However, the cognitive and attitudinal mechanisms explaining inspiration during a creative process remain largely unexplored. Adopting an empirical perspective, inspiration during a creative activity holds the potential to facilitate the generation of exciting new ideas, and it can be evoked by the voluntary allocation of attention to certain new possibilities (perceiving "*something that catches me*" during this search) or by the sudden intrusion of unexpected cues that can attract our attention (perceiving "*something that occurs to me*" while I was not searching for it). But what exactly inspires people during a creative activity, and through which psychological mechanisms can inspirational cues enhance creative performance? The overarching goal of this work is to address this challenging question in the context of cognitive research on creativity. Thus, dissecting the complex and multifaceted phenomenon of

inspiration, we specifically explored whether and which type of stimuli from the environment can inspire the creative process by manipulating the attentional mechanisms by which the inspirational material is embedded into the creative thinking process.

A first clue provided by past research is that highly creative people seem to be more susceptible to paying attention to incidental or apparently "irrelevant" stimuli (Mendelsohn & Griswold, 1966) as well as less prone to screen out this kind of information (Carson et al., 2003; Mendelsohn, 1976; Nęcka, 1999; Rawlings, 1985). The search for and use of apparently irrelevant stimuli during a creative thinking process may therefore play a key role as a source of inspiration for creative people. In the process of creative endeavor, individuals are generally immersed in a huge amount of apparently irrelevant stimuli within their environment, which they may partially perceive and process as inspirational material that can potentially be exploited to come up with new original ideas. Research indeed showed that a wider breadth of attention, or rather, looser attentive filters in creative individuals, may induce them to introduce irrelevant information into the current information processing, which eventually would result in better creative outcomes (Nęcka, 1999).

Among the diverse core personal attitudes characterizing creative people (Feist, 1998; Puryear et al., 2017), Openness, described in terms of aesthetic sensitivity, preference for novelty, intellectual curiosity, and leaning toward nontraditional values (Costa & McCrae, 1992), turns out to be the tightest associate to inspiration (Thrash & Elliot, 2003). Openness seems in fact to predict the frequency of inspiration in everyday life (Thrash & Elliot, 2004), and is one of the personality traits more consistently associated with creative performance and in particular with divergent thinking (DT), i.e., the explorative thinking modality leading to the generation of multiple original ideas (Barbot & Lubart, 2012; Feist, 1998; Guilford, 1959; Puryear et al., 2017). The relationship between Openness and DT has indeed been suggested to be essentially associated to the particularly marked failure of open-minded people to

efficiently filter out irrelevant information (because of their reduced latent inhibition; Peterson et al., 2002), which consequently allows a wider array of information to be used during the idea generation process. Indeed, it has been shown that directing attention to information that is apparently irrelevant for the execution of the task at hand (i.e., irrelevance processing) and being open minded enough to elaborate this information are two fundamental enablers to reach the highest potential outcomes in terms of both real-time creative performance in DT testing and creative success across one's life (Agnoli et al., 2015). Following such literature, we specifically focused on the key role of the personality trait of openness in guiding the attentional processing of apparently irrelevant information in the context of creative ideation.

The current study: Aims and Hypotheses

The analysis of the above mentioned literature essentially shows that irrelevance processing can act as a moderator mechanism between Openness and divergent thinking, in the sense that open people exhibit higher accessibility to irrelevant information that in turn may lead to higher creative outcomes. Although it has been demonstrated that open individuals are more prone to inspiration contagion (Thrash et al., 2017), no work has yet investigated what kind of irrelevant information passes through the attentive filters of creative people to gain creative accomplishments. Is any kind of information from one's environment effective in inspiring better creative outcomes? In other terms, past studies have never explored, to the best of our knowledge, the meaning of irrelevance in the context of inspiration for a creative activity. To explore this issue, the nature of the apparently irrelevant information during a creative activity was examined here taking into account its semantic meaning, which was operationalized in terms of the semantic distance between the information that is central for the execution of a divergent thinking task and the information that is "apparently" irrelevant for its execution. The role of semantic distance in creativity is intuitively incorporated into the cognitive theory of creativity (Beaty et al., 2019; Mednick, 1962), such that creative cognition

involves flexibly combining concepts stored in memory to form novel and useful associations. It has been suggested that a creative outcome emerges from a right balance between effortless bottom-up associative thinking, i.e., flexibility, and demanding top-down control processing, i.e., persistence (e.g., Sowden et al., 2015; Zhang et al., 2020). Consistent with this perspective, we could hypothesize that individuals characterized by a dispositional tendency to be open-minded could take advantage of their attentional ability to embrace irrelevance information allowing them a weaker and more diffuse activation state, which is supposed to facilitate the (re-)combination of semantic information that is usually remotely related.

The question here is whether this irrelevance processing can be primed by any kind of information or whether apparently irrelevant (inspirational) cues are provided with meaning that is specifically related to the ongoing creative activity. We therefore explored whether and to what extent the semantic meaning of apparently irrelevant information for the task at hand plays a role in creative outcomes, taking into consideration the Openness personality trait. Through two experiments carried out with the same sample of participants, two different modalities of attentional processing of apparently irrelevant information have been explored within a divergent thinking task. Specifically, participants were asked to generate alternative uses for some common objects (presented as words of an object), while a series of other inspirational information (words) controlled in terms of semantic distance from the target word, was presented to participants either allowing spontaneous attentional processing (Experiment 1) or forcing the attentional processing (Experiment 2) of this information. During an idea-generating process, indeed, individuals may voluntarily direct attention to inspirational material (i.e., external stimuli) in the surrounding environment. Alternatively, apparently irrelevant stimuli may suddenly impact on the generation of ideas attracting attention during the creative thinking process: irrelevant stimuli could thus break the creative process without individuals' willingness and individuals could be more or less able to inhibit the processing of

this ongoing information and eventually use it for their creative process. The apparently irrelevant information processing was thus explored throughout two well-established experimental paradigms: (Experiment 1) the verbal Alternative Uses Task (Guilford, 1967) and (Experiment 2) the verbal priming paradigm (see Neely, 1991, for a review). In Experiment 1 the irrelevant information was presented together with the information relevant for the divergent thinking task (a target word representing a common object) and participants, whose attentional processing was measured through eye-tracking, were free to decide to which information paying attention before the generation of alternative uses (i.e., "spontaneous" irrelevant information processing). In Experiment 2 the apparently irrelevant information was forcedly presented in the form of semantic priming, such that the (irrelevant) prime words were presented immediately before the presentation of the target word representing a common object, on which participants generated alternative uses (i.e., "forced" irrelevant information processing).

In accordance with the evidence supporting a strong relationship between Openness and irrelevance processing (Agnoli et al., 2015), we firstly expected that individuals characterized by a high level of Openness would be associated with high levels of attentional processing of irrelevant information than low Openness participants.

Secondly, we expected that the Openness facilitatory effect in the processing of apparently irrelevant information would interact with its semantic meaning as key determinant of the outcomes of the divergent thinking performance. Regarding the direction of such interaction, we expected that the way by which irrelevant information is perceived and processed (spontaneously *vs.* forcedly) during the execution of the divergent thinking task could differently impact the pattern of the results. In particular, based on previous approaches to creativity stressing the contribution of associative mechanisms at the basis of semantic memory networks (i.e., spreading activation; Mednick, 1962), when participants are free to

decide whether and to which stimuli to pay attention to, we expected that they first would process the information that is essential for the task at hand (relevant information) and then, if open-minded enough, they would process the semantic nodes of concepts highly related to the relevant information, which could be used for the expression of original ideas. In other words, it is possible that in such spontaneous situation in terms of deployment of attention, open-minded people could be influenced by the processing of relevant information though not able to filter out all apparently irrelevant information. Because of the spreading of activation in the semantic memory associated with the processing of the relevant information, we expected that open-minded people during this spontaneous processing context cannot efficaciously inhibit the information that is semantically related to the activated nodes, thus allowing a wider spreading of the activation mechanism leading to higher original responses. This expectation is also corroborated by the study of the relationship between Openness and latent inhibition, which has been defined as the ability to filter out from the attentional focus stimuli perceived as irrelevant (Lubow, 1989). Open-minded people are indeed characterized by a reduced latent inhibition ability (Peterson & Carson, 2000; Peterson et el., 2002).

Otherwise, when the irrelevant information breaks through an ongoing creative activity, it is possible that the information that is poorly related to the focus of the divergent thinking task foster the construction of original solutions. The presentation of remote (i.e., semantically distant) associative elements as primes before the presentation of the focus of the creative task (i.e., the relevant information) could thus facilitate and increase even more the spreading activation within the semantic memory network in open-minded people. The relevant information would not act in this case as attractor of the spreading of activation, but open-minded participants would be able to exploit remote information to increase the probability to find unusual alternative solutions. This would be in line with the view that a flexible semantic memory structure facilitate creative processing by means of connecting between weakly related

words in the lexicon (Kenett, 2019; Li et al., 2021).

Experiment 1

In the first experiment, we investigated the role of irrelevance processing on the relation between Openness personality trait and divergent thinking, in order to clarify what kind of irrelevant information is beneficial for DT performance in open-minded people. Specifically, the influence of semantic distance between the divergent task-relevant information (i.e., a word extracted from a common conceptual category) and other apparently irrelevant information for the task at hand (i.e., other words or pseudo-words) on divergent thinking was explored. Using a modified version of the verbal Alternative Uses Task (vAUT; Guilford, 1967; see also Agnoli et al. 2015 for a similar experimental procedure), the attentional processing of relevant and irrelevant information by participants was measured by means of an eye-tracking technique.

Methods

Participants

We conducted a power analysis based on Agnoli et al.'s (2015) study. Holding the effect size emerged for the interaction between irrelevance processing and the openness personality trait (Cohen's $f^2 = 0.75$) and adding all hypothesized predictors, including the three-way interaction (irrelevance processing X openness X semantic distance), the analysis conducted with G*Power (Faul et al., 2009) indicated that a sample size of 37 was adequate for detecting this hypothesized effects ($\alpha = .05$, $1 - \beta = .95$). Here, we sought to collect data from over 40 participants.

A total of forty-eight participants (70.8% women; M_{age} = 21.90, *SD* = 5.09; ranging between 18 and 47 years) recruited at the University of Trento (Italy) took part in the experiment. All participants had normal or corrected to normal vision, and none of them reported current or past neurological or psychopathological problems. All participants were

native Italian speakers and gave written informed consent before participating in the experiment. Participants freely and voluntarily agreed to be enrolled in the study and were free to withdraw from the study at any time without providing a reason. The study was carried out in accordance with the principles of the Declaration of Helsinki and in accordance with American Psychological Association recommendations.

Stimuli and apparatus

We selected the word set used in the current study and the semantic measures from Montefinese et al.'s (2013) database. Words consisted of 120 Italian words belonging to diverse conceptual categories (e.g., animals, body parts, clothes, furnishings/fittings, furniture, housing buildings, kitchenware, plants, stationary and vehicles). Stimuli were ranked along several semantic metrics measuring the semantic relationships (e.g., distances) between the words included in the database. For the purpose of the present study, we performed a selection of the words on the basis of two parameters measuring semantic similarity distances: cosine distance and Euclidean distance. The cosine distance between two concepts is the complement of the cosine of the angle between two feature vector representations. Cosine distance values range from 0 (minimum distance or total similarity) to 1 (maximum distance or no similarity). The second semantic distance parameter that we used was the Euclidean distance, which is one of the most familiar and commonly used geometric measures (Montefinese et al., 2013). On the basis of these parameters, starting from a selected list of target words, three categories of semantic similarity distances between two concepts (the target word *vs.* other words) were computed through a ranking of the distribution of the Cosine distance and of the Euclidean distance into three categories: low scores (low semantic distance between a target word and other words), high scores (high semantic distance between the target word and other words), and medium scores (medium semantic distance between the target word and other words). Specifically, irrelevant stimuli (i.e., words) were selected on the basis of the consistency

between the two measures, i.e., when both the cosine measure and the Euclidean distance measure fell into the same category (low, medium, or high distance). From the total words set, to guarantee uniformity, we selected words containing only 5 or 6 letters, obtaining 16 target words associated with, respectively, 16 low semantic distance (LSD) words, 16 medium semantic distance (MSD) words, and 16 high semantic distance (HSD) words (see File S1 in Supplementary Material for the words used in the Experiment and for the metrics used for their selection).

Moreover, in order to include a control condition in the task, which does not convey any meaning in semantic terms, a set of pseudo-words (PSW) were created using the Wuggy algorithm (Keuleers & Brysbaert, 2010; available from http://crr.ugent.be/Wuggy). This algorithm generates pseudo-words by replacing subsyllabic elements of words (onset, nucleus, or coda) by equivalent elements from other words. Through this algorithm we generated a total of 16 pseudo-words, which, based on our list of target words, contained the same number of syllables of the target words. This constraint additionally guaranteed that the pseudo-words equaled the target and the irrelevant words in length.

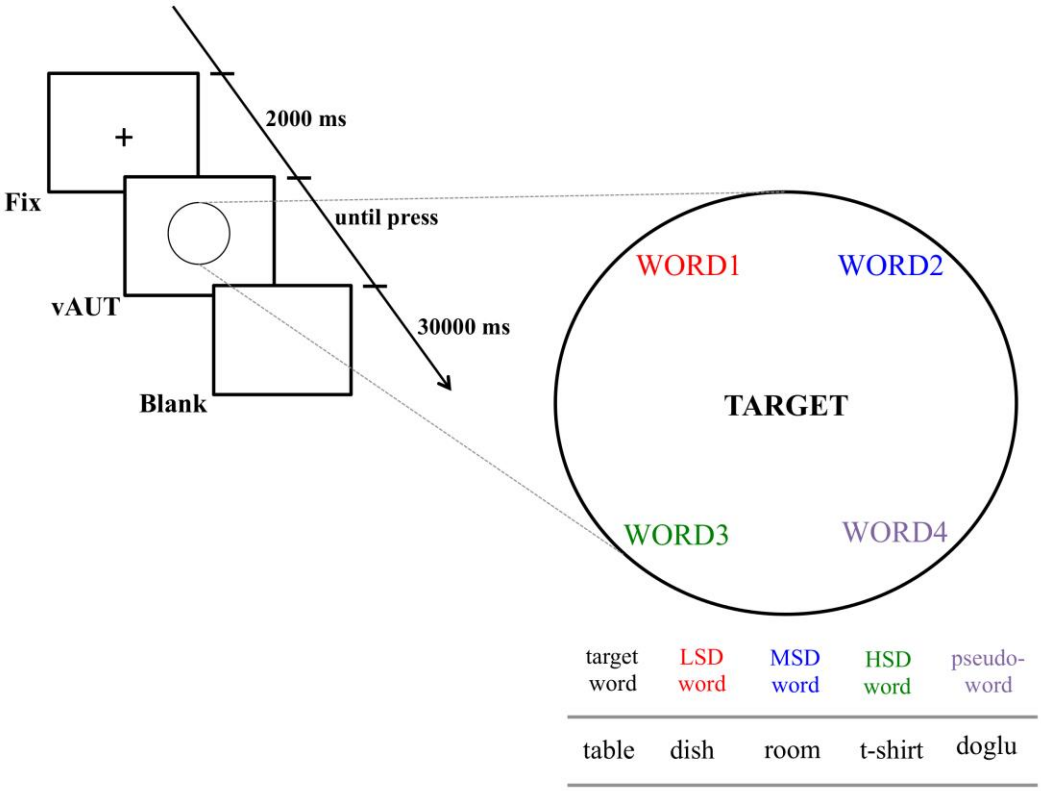
Participants' eye-movements were measured with a Tobii T120 eye-tracker. The eye-tracker was integrated with a 17″ monitor, where all stimuli were presented using the Tobii Studio software. To measure information acquisition, for each stimulus, five different fixed non overlapping areas-of-interest (AOIs) were identified. All five AOIs had the same size, 3.61 cm in width and 1.66 cm in height, and corresponded to the five different words depicted in Figure 1: a central AOI corresponded to the target word, while four peripheral AOIs corresponded to the four words irrelevant for the task at hand (LSD, MSD, HSD words, and pseudo-words). To measure attention allocation, the mean fixation length (fixation duration) and the mean number of fixations (fixations count) to the central and peripheral words were calculated for each participant during the vAUT.

Procedure

Participants sat in a chair placed approximately 60 cm away from the stimulus monitor. The room lights were reduced and at the start of the experimental session participants were informed about the eye-tracking system and how it operated. Before starting the task, participants were introduced with an example trial to familiarize themselves with the task. After 2000 msec of fixation cross at the center of the screen, a set of words appeared on the screen. Participants were required to look at the stimuli as long as they wanted and then to produce as many possible alternative creative uses as they could for the word they saw at the center of the screen (target word). Participants were informed that the target word would be surrounded by other words, which were apparently irrelevant for the task at hand and at which they could decide to look at or not, however, they were reminded that they had to produce alternative creative uses only for the word at the center of the screen. Participants could look at the target word (and eventually at the peripheral words) until they were ready to press the space key and give the answers. Then, a blank screen appeared and participants had 30000 msec to produce all possible alternative uses for the target word they could think of (see Agnoli et al., 2015). For a schematic representation of the experimental procedure see Figure 1.

Figure 1

Experimental trial procedure in Experiment 1



target word	LSD word	MSD word	HSD word	pseudo-word
table	dish	room	t-shirt	doglu

Note. The target word was depicted at the center of the circumference, upon which participants were required to generate many alternative ideas, surrounded by four different (task-irrelevant) peripheral words, characterized by low semantic distance (LSD), medium semantic distance (MSD), high semantic distance (HSD) to the target, and pseudo-words that were used as control stimuli. Examples of diverse words employed in the study are provided on the lower right (please note that these words were translated from the Italian language).

Each participant was presented with four blocks containing four different target words each. The four words (LSD, MSD, HSD and PSW) surrounding each target word (peripheral stimuli) were pseudo-randomly presented in a counterbalanced position across participants. As a consequence, each stimulus (both target and peripheral) could only appear once in the four blocks. An eye-tracker calibration was performed before each block of trials. All

alternative uses produced by participants were recorded by an audio-recorder and off-line transcribed by the experimenter.

At the end of this computer task, participants were asked to complete the NEO Five Factor Inventory (NEO-FFI; Costa & McCrae, 1992) questionnaire, assessing personality and consisting of 60 items. It offers a measure of the Big Five personality traits including Openness to Experience (O), which was the focus of the present work. An example of the O item is "*Sometimes when I am reading poetry or looking at a work of art, I feel a chill or wave of excitement*", to be scored on a 5-point scale (1 = strongly disagree, 5 = strongly agree). The NEO-FFI is widely used and holds adequate reliability and validity (Costa & McCrae, 1992). Acceptable internal consistency was found for the subscale Openness to Experience, with a coefficient alpha of .649.

Assessment of DT performance

In Experiment 1 participants generated a total of 2.053 responses for the presented target words. Three measures of participants' creative-divergent performance were derived from the vAUT: frequency-based originality (i.e., statistical infrequency), rater-based originality, and fluency. We employed both quantitative (i.e., statistical infrequency and fluency) and qualitative (i.e., rated-based originality) measurements for the scoring of the vAUT indexes because frequency-based originality score, which captures the uncommonness dimension, is often confounded by fluency and typically works when the sample size is sufficiently large (Forthmann et al., 2020). Otherwise, qualitative (rater-based) originality is recommended instead of quantitative methods for smaller samples (e.g., Hass et al., 2018; Silvia et al., 2008), as it is able to capture both the remoteness and cleverness indicators of originality besides uncommonness (Agnoli, Mastria et al., 2022; Forthmann et al., 2017; Silvia et al., 2008). The statistical infrequency was obtained by counting the statistical frequencies of each response, compared to the total amount of responses generated for each

target word by all participants, such that 1 corresponds to the lowest frequency (unusual responses) and 0 corresponds to the highest frequency (usual responses). For instance, if the response *scarf* appears 8 times as a response to an alternate use of a *sweatshirt* among 20 productions generated by the sample for this target word, the relative frequency of this response would be .40 (i.e., 8/20) and, consequently, its statistical infrequency would be .60 (i.e., 1 - .40; see Forthman et al., 2020). The following criteria were used to adapt the database for the statistical infrequency calculation: (i) superfluous words such as "*used for*" have been suppressed; (ii) singular and plural words have been made consistent; (iii) diminutives have been prevented; and (iv) other slight changes have been introduced to facilitate the identification of similar responses (see Reiter-Palmon et al., 2019).

Regarding the originality scoring, two external judges were involved to independently rate the originality of participants' responses to each target word (Silvia et al., 2008). Each recorded response was previously transcribed into a spreadsheet and then sorted alphabetically within each target word. This method ensured that the raters were blind to several factors that could bias their ratings: (i) the response serial position in the set, (ii) the total number of responses in the set, and (iii) the preceding and following responses. The raters read all the responses prior to scoring them on a five-point scale (from 1 = *not at all original* to 5 = *highly original*), and they scored the responses separately using the *uncommonness*, *remoteness*, and *cleverness* dimensions (Silvia et al., 2008; Wilson, et al., 1953). Inter-rater reliability calculated on the total number of responses produced by participants was good (ICC = 0.86). In case of important discrepancies in ratings, raters reviewed and assigned scores by consensus. Finally, fluency was scored as the total number of responses generated by each participant.

Data Analysis

In order to investigate the influence of the nature of the irrelevance information and of

the individual differences in Openness on creative-divergent performance, changes in statistical infrequency, originality and fluency were tested in three separate generalized linear mixed models (GLMM) and treated as repeated dependent variables. Robust error estimation was used to control for the possible effect of outliers (Wu, 2009), controlling for the random effect of subjects. For each dependent variable, SEMANTIC DISTANCE[1] (four levels: LSD, MSD, HSD, and PSW) was entered into the models as within-subjects factors, whereas FIXATION DURATION (to peripheral words) and OPENNESS were treated as continuous fixed effects. The underlying rationale was that, based on the assumption that there is a fixed relationship between each level of explanatory variables (i.e., FIXATION DURATION and OPENNESS) and its corresponding outcome (i.e., creative-divergent performance indexes) across all observations, these fixed effects may vary from one observation to another. Therefore, specifying the random effect of subjects we basically considered individual differences, allowing us to distinguish the variability of the subject effect from the variability expressed by the relationships between the explored variables. The main effects, two- and three-way interactions between the previous variables were added to the models. Where appropriate, Bonferroni corrections were used for *post-hoc* comparisons. Even if presenting effect sizes when performing linear mixed models is a complex and debated issue, we decided to report several effect sizes estimates for our models, in order to allow a comparison with the previous literature (e.g., Agnoli et al., 2015). Specifically, effect sizes in mixed linear models were calculated using a global variance-explained measure described in Xu (2003, Ω_0^2 index) and two approximate R^2 calculated using Nakagawa and Schielzeth (2013) methods and describing the variance marginally explained by fixed effects only ($R^2_{LMM(m)}$)

[1] Before proceeding to the description of the analysis, we will describe the terminology that will be used throughout the article. The notion of "semantic distance" follows the label adopted by previous studies that have estimated the measures and statistics on semantic distance at the concept level (Montefinese et al., 2013; Kenett et al., 2017). Semantic distance will be also conceived as the degree of similarity between concepts (i.e., the closer that two concepts are, the more similar their semantic representations).

and the variance explained by both fixed and random effects (R^2_{LMM}). A note on the method to calculate R^2 indices from the SPSS output of linear mixed-models is available as a supplemental spreadsheet, along with all effects sizes calculations reported in this work.

Data and analysis code for this study are available at request to the corresponding author. The study was not preregistered.

Results

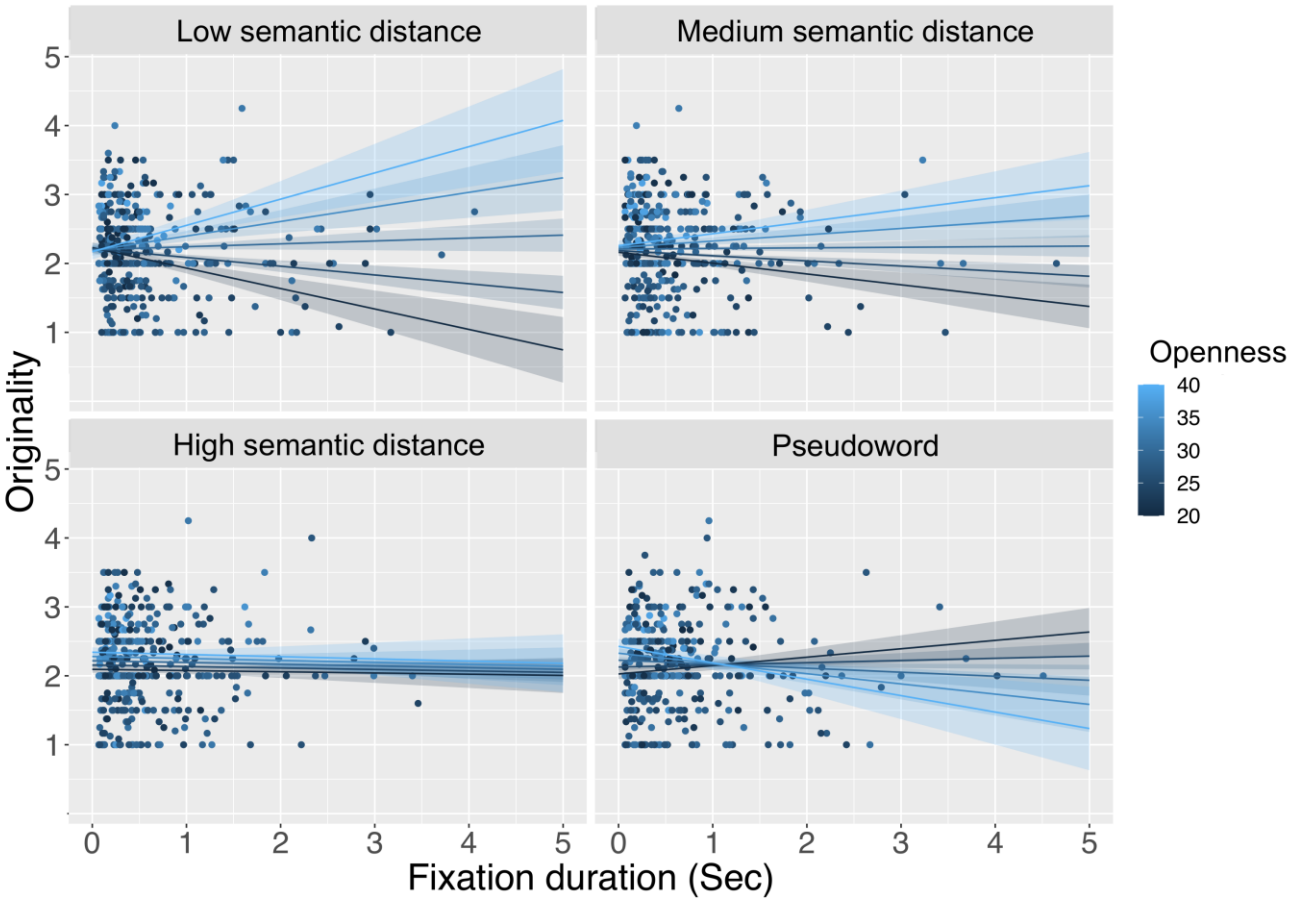
Descriptive statistics and correlations between all Experiment 1 variables are presented in Table 1.

The first GLM model on participants' statistical infrequency did not show any significant main or interactions effects (all F*s* < 1.170, *ps* > .320, $\Omega_0^2 = .162$, $R^2_{LMM(m)} = .004$, $R^2_{LMM} = .208$). The analysis on originality scores revealed instead a two-way interaction between SEMANTIC DISTANCE and FIXATION DURATION ($F_{3,1.527}$ = 4.266, p < .01), which was further qualified by a SEMANTIC DISTANCE x FIXATION DURATION x OPENNESS interaction ($F_{3,1.527}$ = 4.697, p < .01). No other significant main or interactions effects emerged from the analysis (all F*s* < 1.099, *ps* > .295). The GLMM global effect size on originality scores indicated approximately 40% of the variance explained by the model ($\Omega_0^2 = .449$, $R^2_{LMM(m)} = .011$, $R^2_{LMM} = .409$). As clearly depicted in Figure 2, this result indicated that, in comparison to (control) pseudo-words, an increase of the processing (i.e., fixation duration) of the irrelevant information which were highly (b = 0.019, $t_{1.527}$ = 2.540, p = .011, 95% CI=[0.004, 0.034]) and moderately (b = 0.022, $t_{1.527}$ = 3.549, p < .001, 95% CI=[0.010, 0.035]) semantically related to the target word predicted higher originality scores when it was associated with an increase of individual Openness level. In other words, when an increase of the Openness trait was associated with an increase of the processing of apparently irrelevant information, which were highly or moderately related to the object of the creative activity, higher originality scores emerged in participants'

responses. Analysis of participants' fluency scores revealed a main effect of FIXATION DURATION ($F_{1,1737}$ = 4.649, p < .05) without any other main or interaction effects (all F*s* < 3.674, *ps* > .055, $\Omega_0^2 = .416$, $R^2_{LMM(m)} = .014$, $R^2_{LMM} = .400$).

Figure 2

The response originality associated to the duration of fixation of irrelevant stimuli as a function of the Openness level.



Note. The Figure depicts the predicted values of the response originality with the increase of the duration of fixation of the irrelevant stimuli at low (top - left), medium (top- right), high (bottom - left) semantic distance from the target stimulus and of the control stimuli (pseudowords, bottom - right) as a function of different Openness values (light blue = high values; dark blue = low values). A significant increase in response originality emerged when

longer fixation durations of irrelevant stimuli at low and medium semantic distance from the target stimulus were associated with high Openness levels (as depicted in the top-left, and in the top-right panels). Shaded areas denote 95% confidence intervals.

A similar pattern of results emerged when considering fixation count instead of fixation duration to peripheral words in all three models. Analyses regarding fixation count are described in the Supplementary Material (see S2).

Discussion

In Experiment 1, we directly assessed the influence of semantic distance between the divergent task-relevant information (target word) and other apparently irrelevant information for the task at hand (peripheral words) on the divergent thinking performance. We confirmed our expectations finding that open-minded people seem to be "inspired" and thus stimulated to produce more original ideas by apparently irrelevant information. Moreover, when participants were free to decide whether and to which irrelevant stimuli to pay attention to, information characterized by low and medium semantic distance to the target of the divergent thinking task led to higher originality in open-minded people.

Experiment 2

In Experiment 1 the processing of apparently irrelevant information was therefore "spontaneous" in its nature, i.e., guided by individual differences in the natural processing of environmental information (e.g., by Openness), in the sense that participants during the vAUT were free to decide for how long and to which kind of stimuli to look for. But what happens if apparently irrelevant information breaks through an ongoing creative activity in association with different openness levels? To answer this question, in a different experimental session, the

same sample of participants of Experiment 1 were required to perform a verbal priming paradigm in which they were asked to generate an alternative unusual use for some targets words. Using the same group of participants allowed us to control the distribution of the Openness trait, changing only the stimuli presentation modality. It is worth highlighting that, differently from Experiment 1, in this experiment we asked participants to produce only the first alternative use that comes to their mind, since priming effects typically have a hasty decay time (Foss, 1982). Here, the target words were preceded by prime words either lowly, moderately, or highly semantically related to the target words, or by prime pseudo-words (control stimuli), thus forcing irrelevance information into the creative process instead of leaving their processing free for participants.

Participants

See the participants section of Experiment 1. The two experiments were distanced by about one week from each other.

Stimuli

A new set of 16 target words associated with 16 prime words, belonging either to LSD, MSD, HSD between the latter and the target word, or to PSWs, were generated (see S1 in Supplementary Material). The words (and pseudo-words) selection criteria were the same as those used in Experiment 1. All participants saw the same set of target words in a pseudo-randomized order, and each of the four prime words (associated with the target word) were presented in a counterbalanced order between participants.

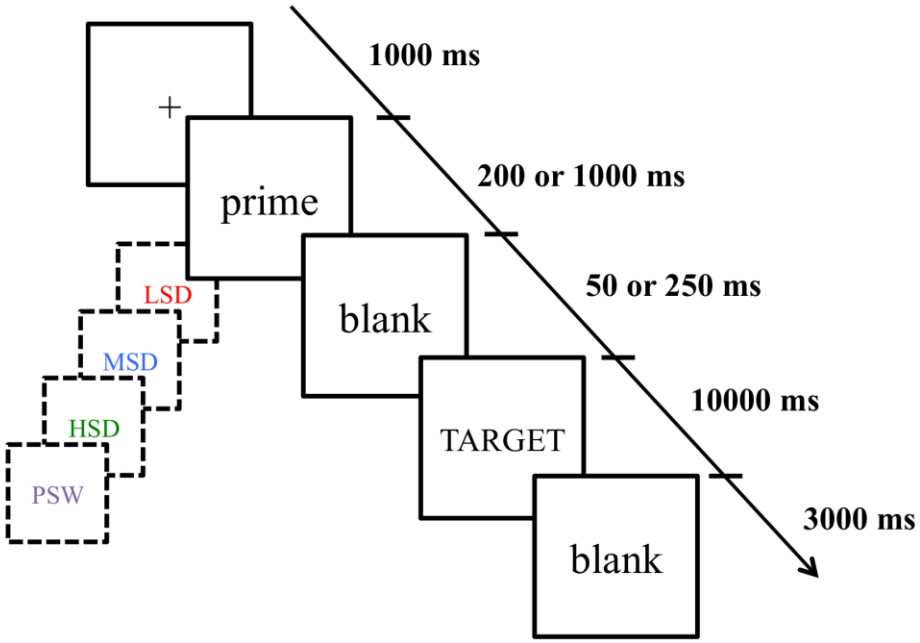
Procedure

The sequence of the events of each trial is schematized in Figure 3. Words were individually presented at the center of the computer screen in white uppercase (TARGET WORDS) or in white lowercase (prime words) letters against a black background. One practice trial preceded the experimental trials. Participants were instructed to produce the first

alternative use that comes to their mind, that is, the first uncommon use for the words written in uppercase letters within 10.000 msec. Each trial began with a fixation cross appearing at the center of the screen for 1.000 msec. After the fixation cross, a prime word appeared either for 200 msec or 1.000 msec. The prime word was followed by a blank screen for 50 msec or 250 msec. The blank screen was replaced by the target word, which remained on the screen until 10.000 msec, during which participants were required to produce the alternative use. All responses produced by participants were recorded by an audio-recorder and off-line transcribed by the experimenter. A blank screen of 3.000 msec separated each trial. Half of the participants received the prime-target pairs at a relatively short stimulus onset asynchrony (SOA) of 250 msec, while the other half received the prime-target pairs at a relatively long SOA of 1.250 msec. This SOA manipulation was justified by the need of potentially distinguishing between more automatic and more controlled processes (see Balota et al., 2008 for a similar experimental procedure; see also Balota et al., 1992; Burke et al., 1987; den Heyer et al., 1983; Favreau & Segalowitz, 1983). It has been indeed suggested that automatic spread of activation is the relevant mechanism at a short interval between presentation of prime and target words (SOAs < 400 msec), whereas controlled or attentional processes are engaged only at SOAs greater than 400 msec (Neely, 1977).

Figure 3

Sequence of events on each trial of Experiment 2



Note. The target word, upon which participants were required to generate an alternative idea, was preceded by prime words belonging either to a low semantic distance (LSD), a medium semantic distance (MSD), or a high semantic distance (HSD) from the target word. Pseudo-words (PSW) were included as control stimuli.

Assessment of DT performance

In Experiment 2 participants generated a total of 606 responses for the presented target words. Specifically, they produced 156 responses to target words preceded by LSD prime, 140 responses to target words preceded by MSD prime, 155 responses to target words preceded by HSM prime, and 155 responses to target words preceded by PSW. Thus, from the total of 768 trials, a percentage of 21.09 trials were excluded from the analysis, as participants did not vocalize any answer or they pronounced nonsense words.

Two measures of divergent thinking performance were derived here from the verbal priming paradigm: statistical infrequency and originality. To guarantee compatibility with

Experiment 1, the same scoring methods for these measures applied in Experiment 1 were employed here. Regarding originality scoring, the inter-rater reliability calculated on the total number of responses produced by participants was excellent (ICC = 0.93). Besides these divergent thinking measures, the response time (RT) following the presentation of each target word was calculated. In addition, the same participants' scores of Openness derived from NEO-FFI as applied in Experiment 1 were considered in this second Experiment.

Data Analysis

In order to investigate the role of the semantic distance of the prime words from the target word along with the role of the personality trait of Openness on creative-divergent performance, changes in statistical infrequency and originality were tested in two separate GLMMs and treated as repeated dependent variables. Also in this case, robust error estimation was used to control for the possible effect of outliers (Wu, 2009), controlling for the random effect of subjects. For each dependent variable, PRIME (four levels: LSD, MSD, HSD, and PSW) was entered in the models as within-subjects factors, while SOA (two levels: short, long) was entered as between-subjects factor, and OPENNESS treated as continuous fixed effect. The main effects, two- and three-way interactions between the previous variables were added to the models. Where appropriate, Bonferroni corrections were used for *post-hoc* comparisons. Again, mixed model effect sizes were calculated using a global variance-explained measure (Ω_0^2) and two R^2 approximations characterizing the variance marginally explained by fixed effects only ($R^2_{LMM(m)}$) and the variance explained by both fixed and random effects (R^2_{LMM}). More information on indexes computation for the second experiment can be found in the Supplementary Material.

Data and analysis code for this study are available at request to the corresponding author. The study was not preregistered.

Results

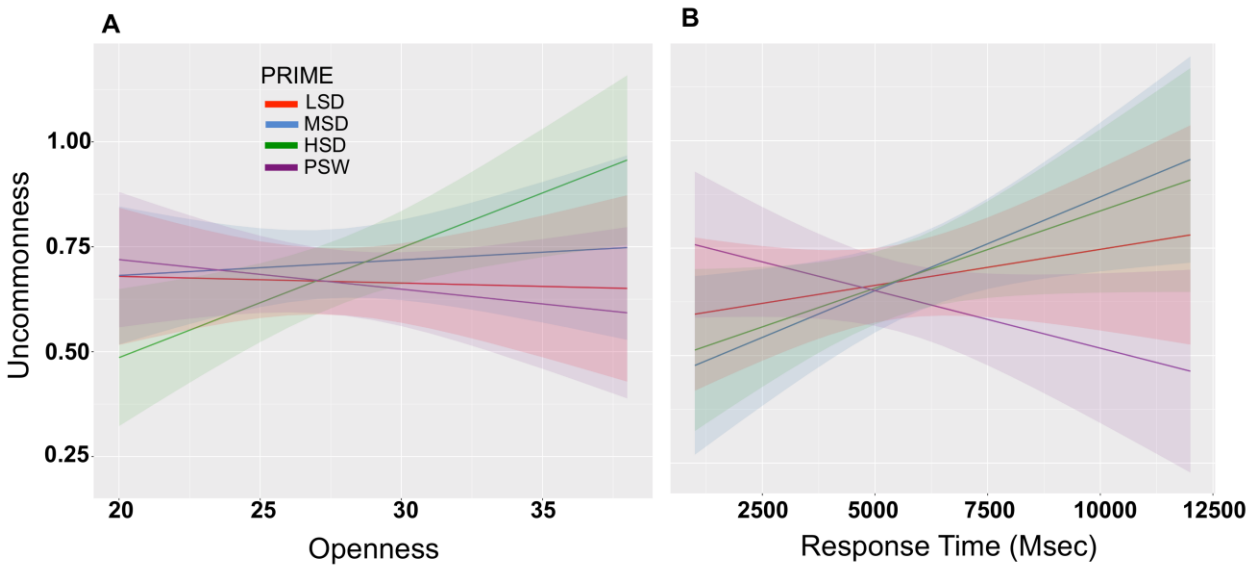
Creative performance

Descriptive statistics and correlations between all Experiment 2 variables are presented in Table 2.

Differently from Experiment 1, here analysis on participants' originality did not show any significant main or interactions effects (all Fs < 0.678, *ps* > .410, $\Omega_0^2 = .224$, $R^2_{LMM(m)} = .010$, $R^2_{LMM} = .185$). However, interestingly, analysis on statistical infrequency scores revealed a main effect of PRIME ($F_{3,588}$ = 3.138, $p < .05$), which was further qualified by the interaction between PRIME and OPENNESS ($F_{3,588}$ = 3.826, $p < .05$). No other significant main or interactions effects emerged from the analysis (all Fs < 1.669, *ps* > .173). The model explained nearly 13% of statistical infrequency scores ($\Omega_0^2 = .147$, $R^2_{LMM(m)} = .032$, $R^2_{LMM} = .124$). As shown in Figure 4a, the PRIME x OPENNESS interaction indicated that individuals with a higher Openness level were characterized by a higher statistical infrequency scores only when prime words were lowly ($F_{1,154}$ = 8.281, $p < .01$, b = 0.018, t_{154} = 2.878, $p < .01$, 95% CI = [0.006, 0.031]) semantically related to the target word, in comparison to the pseudo-word control condition. No other effects were significant (all Fs < 0.277, *ps* > .599).

Figure 4

The response uncommonness associated to the Openness and to the Response Time as a function of prime stimuli.



Note. The figures depict the predicted values of response uncommonness with the increase of the Openness values (panel A) and of the Response Time (panel B) as a function of the presentation of prime stimuli (words) at low (red lines), medium (blue lines), high (green lines) semantic distance from the target stimulus, and of control stimuli (pseudowords, violet lines). Uncommonness has been measured as statistical infrequency (i.e., reversed frequency of appearance of a response in the sample) and it is distributed on a scale ranging from 0 (extremely common response, produced by all participants) to 1 (extremely uncommon response, produced only one time within the sample). Shaded areas denote 95% confidence intervals.

Response times

In order to further clarify the effects emerged in the previous analyses, differences in statistical infrequency were explored in relation with the RT taken by participants to generate an alternative use to the target word as a function of diverse prime words. Thus, in a separate GLMM, we used statistical infrequency scores as a dependent variable, PRIME (LSD, MSD, HSD, and PSW) as a within-subjects factor, SOA (short, long) as a between-subjects factor, and RT as continuous fixed effect, controlling for the random effect of subjects. Analysis on

statistical infrequency scores revealed a main effect of RT ($F_{1,502}$ = 8.153, p < .01), which was further qualified by the interaction between PRIME and RT ($F_{3,502}$ = 2.562, p = .054). No other significant main or interactions effects emerged from the analysis (all F*s* < 2.148, *ps* > .093). The model explained around 11% of the variance ($\Omega_0^2 = .136$, $R^2_{LMM(m)} = .055$, $R^2_{LMM} = .111$). Consistently, as shown in Figure 4b, the PRIME x RT interaction demonstrated that, in association with prime words which were lowly ($F_{1,135}$ = 7.540, p < .01, b = 0.000, t_{135} = 2.746, p < .01, 95% CI = [0.000, 0.000]) and moderately ($F_{1,115}$ = 9.302, p < .01, b = 0.000, t_{115} = 3.050, p < .01, 95% CI = [0.000, 0.000]) semantically related to the target word, an increase in the times taken by participants to generate an alternative use predicted higher statistical infrequency scores. In other terms, an increase of the response time was conductive to more uncommon uses when it was associated with prime words of objects poorly (i.e., lowly and moderately) related to the target object. No other effects were significant (all F*s* < 0.128, *ps* > .721).

Discussion

Experiment 2 consistently highlighted the importance of the semantic meaning of apparently irrelevant information in open-minded individuals in predicting their creative performance. In Experiment 2 when irrelevance information was forced within the process, results suggest that prime words characterized by high semantic distance from the target words may prime the generation of more uncommon ideas in the first alternative uses elicited starting from the target word. This was confirmed by the result showing that generating an alternative idea to a target word preceded by moderately and lowly semantically related prime required higher investment of cognitive resources (longer RTs), as compared to the other prime words, leading to more uncommon uses.

General discussion

Creators have long claimed that inspiration is essential to the creative process, but until recently, researchers have poorly experimentally investigated this claim (see Oleynick et al., 2014 for a review). The present work offers an empirical investigation of the influence of apparently "irrelevant" stimuli in the creative thinking process aimed at understanding whether this information, characterized by diverse contextual meanings, can modulate the expression of an idea in people characterized by a specific tendency to process apparently irrelevant information, i.e., open-minded individuals. Open-mindedness is in fact one of the personality characteristics that mostly predict everyday inspiration and divergent thinking (Feist, 1998; Kaufman, 2013; Thrash & Elliot, 2004). Here, the concept of irrelevance for a creative task was precisely examined in terms of the semantic distance between the target word of a DT task at hand and other words that are apparently not related to the DT task, with the purpose to understand whether the meaning of irrelevant information could be a primary determinant in inspiring the creative outcomes in open-minded people. Consistent with previous findings (Agnoli et al., 2015), results from Experiment 1 showed that individuals characterized by a high level of Openness paid attention for longer to irrelevant stimuli in comparison to individuals characterized by a low Openness level, and this longer irrelevance processing helped them to generate more original ideas. This is in line with the evidence that the processing of apparently irrelevant information is typically associated with participants' creative achievement and creative performance (Agnoli et al., 2015; Carson et al., 2003). More interestingly, we found that the irrelevance has a meaning, i.e., that not all processed irrelevant information is able to affect (i.e., inspire) the creative process in open-minded people. Consistently with our expectations, the direction of this interaction seems to change as a function of the way by which open individuals perceive and process the irrelevant information during a creative-divergent task. In particular, when open-minded participants were free to explore information from their environment (Experiment 1) they got "inspired"

only by the irrelevant information that was highly or moderately related to the target of the ongoing creative task, as their creative performance increased in terms of ideas originality specifically when it was associated with an increase in the processing of these kind of stimuli. This finding is in line with the general notion that the creative process is an active process working upon the semantic memory structure, such that, following a spreading activation model (Collins & Loftus, 1975; Mednick, 1962), when a concept in the semantic network is activated, activation spreads from it to all of its directly related neighbors (Volle, 2018). We could suppose that the spreading of activation into the semantic memory network associated with the processing of the relevant word (which was the first stimulus processed by the participant, because of the fixation cross) could have facilitated the processing of the semantic nodes that were more closely related to this information (Volle, 2018). As a consequence, open-minded people were facilitated in the attentional processing of apparently irrelevant information that was highly or moderately related to the relevant information, because of the pre-activation of closely related nodes into their semantic network. Otherwise, when irrelevance information was "forced" within the process through a verbal priming paradigm (Experiment 2), results showed that prime words characterized by high and moderately semantic distance to the target words were able to stimulate the generation of more uncommon uses in the participants' first responses to the target object, again when they were associated with high levels of Openness. These results suggest a prime effect exerted by the apparently irrelevant stimuli that were scarcely (or moderately) related to the target object on the first alternative use produced by open-minded participants, who probably efficiently exploit the processing of this kind of information to construct original solutions. It is possible that the presentation of highly unrelated information to the target word could have facilitated the flexible access to remote concepts, which is believed to be a key aspect for the generation of creative thoughts (Kenett, 2019; Li et al., 2021). This seems also to be in line with recent

evidence on the significance of switching of idea categories for divergent thinking (Mastria et al., 2021; Nusbaum & Silvia, 2011).

Overall, both experiments seem to suggest that the nature, i.e., contextual meaning, of the apparently irrelevant information, measured in terms of semantic similarity to the target of the divergent task, is crucial in determining the creative performance in open-minded individuals. The (apparently) contrasting pattern of results emerged between the two experiments can be at least partially explained by the two diverse experimental designs. In Experiment 1, participants were specifically asked to process the relevant information for the creative task at hand (a word on the center of the screen), whose processing was facilitated by a fixation cross. Participants were indeed instructed to fixate the cross at the center of the screen and the target object would have appeared in its correspondence. Then, during the processing of the relevant information, participants were free to choose whether to process also the peripheral apparently irrelevant information. In other words, participants were actually engaged in performing a creative activity, and in fact most of their attentional resources was concentrated on the stimulus that was central for the ongoing task (the target stimulus, on which the fixation length was indeed longer than on the irrelevant peripheral stimuli, $ps < 0.001$, confirming past research, Agnoli et al., 2015; 2019). At the same time, they were free to explore other (apparently irrelevant) stimuli depending on their individual dispositions. Differently, in Experiment 2 the processing of irrelevant information (prime words) preceded the processing of relevant information. Here, we could suppose that the spreading of activation into the semantic memory network associated with the processing of the apparently irrelevant stimuli was not affected by the semantic processing of the relevant stimulus. In this case, it is possible that highly unrelated semantic nodes that were forcedly introduced into the creative thinking process could have facilitated the activation of more remote associations necessary to the generation of uncommon solutions in participants

characterized by lower inhibitory abilities. Regarding Experiment 2, from a methodological point of view, it is important to highlight that in this case the meaning of apparently irrelevant stimuli modulated participants' ideation activity regardless of the SOA between the prime-target pairs. This result seems to suggest that the use of a semantic priming paradigm in the context of creative activity is not able to distinguish between more automatic and more controlled processes, probably due to the challenging nature of the creative-divergent task.

Our results also indicate that the way in which individuals are able to inhibit or, conversely, process the apparently irrelevant information (spontaneously *vs*. forced) during the execution of a divergent thinking task seems also to play a key role in determining the direction of the results in terms of creativity outcomes (uncommonness *vs.* originality). In the present work, apparently irrelevant information for the task at hand was indeed presented in the form of words that could either catch participants' attentional resources during the creative-divergent task at hand or mandatorily arise in the divergent thinking process. Two differential mechanisms in the attentional filtering of apparently irrelevant information (i.e., distractors) during creative activity in association with the openness trait were explored: the ability to screen out irrelevant information that is present in the environment and the ability to inhibit intervening and interfering information for the ongoing task. In both studies highly open-minded individuals emerged to have lower inhibitory abilities than lowly open-minded participants, as already demonstrated in past research showing low latent inhibition in association with Openness (Agnoli et al., 2015; Carson al., 2003: Peterson et al., 2000). In Experiment 1, the irrelevant information that was highly or moderately associated with the focus of the DT task at hand attracted open-minded participants' attentional resources during creative ideation, leading to high levels of originality. Otherwise in Experiment 2, irrelevant information, which was forced within the ideational process, induced an increase of the uncommonness (i.e., statistical infrequency) of the responses in the same open-minded

individuals when it was semantically far from the DT target. It follows that (a) different effects of the semantic distance on creative outcomes emerged as a consequence of the modality of presentation of the irrelevant stimuli (i.e., potentially inspiring distractors) and (b) an involvement of different divergent indexes emerged as a consequence of the different experimental paradigm used in the two studies. Differently from Experiment 1, the use of priming stimuli in Experiment 2 could have determined a reduction of the processing time of irrelevant information. As a consequence, we can assume that only highly "contrasting" (irrelevant) information could have been effective in increasing the spreading of activation in the semantic memory structure, thus raising the possibility to produce more uncommon ideas. Related to this latter point, no effect on response rater-based originality emerged in Experiment 2, but only an effect on the uncommonness (i.e., statistical infrequency) of the first alternative use. It should be noted that, even if originality and uncommonness are highly related concepts (uncommonness is one of the defining criteria for originality, see Christensen et al., 1957; Silvia et al., 2008), they provide diverse dimensions of the creative performance. Whereas statistical infrequency (calculated by a frequency-based method) captures the uncommonness of the responses within the sample, originality (calculated by a rater-based method) involves also qualitative elements (i.e., remoteness and cleverness) in the scoring of the responses (e.g., Forthman et al., 2020). Moreover, originality needs time to emerge during a DT task, because of the typical serial order effect (Christensen et al., 1957; Johns et al., 2001; Milgram & Rabkin, 1980; Phillips & Torrance, 1977). In Experiment 2, in order to explore the priming effect on creative performance, only one response was required from participants (i.e., the first alternative use for the object that came into their mind), whereas in Experiment 1 participants had 30 seconds to produce as many responses as they could, allowing a serial production of alternative responses and thus permitting originality to emerge as a consequence of this longer ideation process. It is worth highlighting that no

effect of irrelevant information emerged on the first response (originality and uncommonness) in Experiment 1 (see Supplementary Material). We can therefore assume that the different results on creative performance between the two experiments are related to the different stimuli presentation and to the diverse timing of the ideation activity.

Albeit extremely interesting, these results need to be replicated and further explored in future research, in order to clarify the mechanisms by which Open-minded people process irrelevant information at varying semantic meanings in the context of these two different experimental designs. This is especially relevant considering that the internal consistency measure for Openness, on which we based our analysis, was quite poor (coefficient alpha of .649). Further studies are needed to clarify the differential effect of stimuli presentation modality and of the idea generation timing on the ability to be inspired by irrelevant information during a creative task. Moreover, a replication of the effects emerging in the two experiments here described would be needed using also different samples in two different studies. However and interestingly, differently from previous studies (Abraham, 2014; Gruszka & Nęcka, 2002; Mednick et al., 1964; Rossmann & Fink, 2010), the present work deals with, for the first time to the best of our knowledge, a direct examination of the meaning of external/apparently irrelevant information (by the use of semantic measures) in inspiring (i.e., increasing) the creative process, taking into consideration individual differences in terms of the openness personality trait. It is worth highlighting that this work does not allow a full understanding of the complex process of inspiration, which has been associated also with the process of actualization of a creative idea and with the motivation to realize it (Trash, 2021). The present work can however provide a first understanding of the interacting and inspiring role of external information in the divergent generation of alternative ideas, by offering an exploration of the attentive and memory mechanisms involved in this interactive process and considering individual differences in Openness and

contextual factors as essential in this interaction that can be considered as the first spark for an inspiration process.

Conclusions

The findings that have emerged from the present work suggest that inspiration has meaning for creative ideation. No effect of pseudo-words (control stimuli) emerged in the two experiments; only words that had a semantic meaning relevant to the task at hand were able to inspire the divergent thinking process. The impact of the meaning of this apparently irrelevant information seems however to depend on the context and on the conditions under which this information is perceived and processed. The processing modality emerged to be a critical factor in determining the direction of the efficacy of apparently irrelevant stimuli in inspiring the creative process. Interestingly, inspiration during a creative activity seems to require an adequate level of Open-mindedness in order to include apparently irrelevant information into the creative process. Inspiration emerged therefore from this work as a multidimensional phenomenon defined by individual tendencies in the processing of external information (i.e., Open-mindedness), the meaning of apparently irrelevant stimuli for the task at hand, and contextual factors.

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Table 1. Descriptive statistics and correlations among the variables in Experiment 1

Variable	*n*	Mean	*SD*	*Min*	*Max*	*1*	*2*	*3*	*4*	*5*	*6*
1 Fluency	48	2.58	.98	.69	4.56	_					
2 Originality	48	2.20	.44	1.12	2.94	.032	_				
3 Uncommonness	48	.63	.12	.44	.88	.534**	.224	_			
4 Fix. Duration Irrelev. Inform.	48	6.70	4.19	1.19	20.06	.503**	.161	.301*	_		
5 Fix. Count Irrelev. Inform	48	14.37	7.66	6.29	42.89	.335*	.069	.231	.712**	_	
6 Openness	48	27.81	4.53	20	38	-.152	.148	-.055	.003	.035	_

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

Table 2. Descriptive statistics and correlations among the variables in Experiment 2

Variable	*n*	Mean	*SD*	*Min*	*Max*	*1*	*2*	*3*
1 Response Times	48	5651	1149	3333	8636	_		
2 Originality	48	2.29	.32	1.62	3.38	-.017	_	
3 Uncommonness	48	.65	.16	.17	.93	.133	.413**	_

Note. *$p < .05$, **$p < .01$. Response times are expressed in milliseconds.