Captured by associations: Semantic distractibility during analogical reasoning in schizophrenia

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\begin{abstract}
Impaired cognitive control, for instance increased distractibility in simple conflict tasks such as Stroop, is considered one of fundamental cognitive deficits in schizophrenia patients. Relatively less is known about patients' proneness to distraction in more complex, longer-lasting cognitive tasks. We applied the four-term analogies with and without distraction to 51 schizophrenia patients in order to examine whether they display increased distractibility during analogical reasoning, and to test which kind of distractors (semantic, categorical, or perceptual) elicits their strongest distraction, as compared to 51 matched controls. We found that (a) both groups reasoned by analogy comparably well when distraction was absent; (b) in both groups distraction significantly decreased performance; (c) schizophrenia patients were significantly more distracted than the controls; (d) in both groups the semantic distractors were selected more frequently than the categorical distractors, while the perceptual distractors were virtually ignored; as well as (e) in both groups distraction in the four-term analogies was unrelated with distractibility in the simple perceptual conflict task, suggesting that these two distraction types tap into different cognitive mechanisms. Importantly, a significantly stronger distractibility in the schizophrenia group could not be explained by their lower intelligence, because the two groups were matched on the fluid reasoning test. We conclude that during complex cognitive processing schizophrenia patients become captured by irrelevant semantic associations. The patients are also less willing to critically evaluate their responses.
\end{abstract}

1. Introduction

Decades of research tracked the most significant markers of cognitive decline in schizophrenia. Distorted inhibitory control is one such marker, as patients commonly display increased distractibility, that is, failures in avoiding salient yet irrelevant features of the situation, which can likely divert their thinking from following the target information (Addington et al., 1997; Freedman and Chapman, 1973).

Distractibility in schizophrenia has so far been mainly investigated using attention control paradigms such as the Stroop and flanker tasks, as well as selective attention paradigms such as the dichotic listening task. Overall, the majority of studies indicated patients' attentional inhibition dysfunctions resulting in substantial distractibility (for review see Chieffi et al., 2015; Luck et al., 2019; Oltmanns, 1978).

Relatively less is known about the effects of distraction in schizophrenia patients in relatively more complex and longer-lasting cognitive tasks, involving reasoning, problem-solving, and decision making. Notably, the attention control and selective attention paradigms studied so far tap into distraction driven primarily by instantaneous perceptual conflict (e.g. between the medial and lateral stimuli in the flanker task, or between the to-be-ignored and target channel in the dichotic listening task), therefore patients' distractibility in these so-called conflict tasks need not directly translate into their distractibility in complex tasks, for at least two reasons.

Firstly, in longer-lasting, multistage processing, typical for reasoning and problem-solving tasks, participants have enough time to revise their responses before completing a trial, even if at earlier stages their attention had been captured by a distractor. Consequently, in complex cognitive tasks, unlike in simple conflict tasks, schizophrenia patients might eventually avoid following distraction by means of top-down control allowing them to correct a previously distorted course of reasoning.

Secondly, not only perceptual, but also other sources of distraction, including semantic or categorical relatedness, might play a role in
complex cognitive tasks. Of special importance are abnormalities in semantic processing commonly reported in schizophrenia. Decades ago, Maher (1983) suggested that speech intrusions and communication disturbances in schizophrenia are related to increased activation of semantic associations generally, and with weak inhibition of irrelevant associations more specifically. Numerous EEG studies that analyzed event-related potentials during the semantic priming and lexical decision task confirmed increased priming effects in patients (for review see Pomarol-Clotet et al., 2008; Wang et al., 2011). Presumably, patients’ attention is more likely to instantly drift toward objects related semantically. This assumption seems to be in line with existing studies applying the Hayling Sentence Completion Test (HSCT). In HSCT, participants are asked to complete a given sentence either meaningfully (initiation condition, e.g. “The dough was put in the hot…” or in a way that does not make sense (suppression condition; e.g. “The dough was put in the hot… train”). Martin et al. (2016) reported that in the suppression condition patients more often, as compared to healthy controls, produced in incorrect trials the words which were semantically related to the subject of the sentence (e.g. bread) or to the correct response (e.g. sink). In summary, the complex, semantically loaded cognitive tasks may yield richer patterns of distractibility than the patterns observed in simpler tasks.

Our goal was to compare distractibility during analogical reasoning – a hallmark example of a longer-lasting, complex cognitive task investigated in clinical studies (Krawczyk et al., 2008) – in a relatively large group of schizophrenia patients (as compared to research done so far) versus healthy controls. The two groups were matched with regards to cognitive ability level (fluid intelligence). Applying an analogy task allowed introducing three different sources of distraction: semantic, categorical, and perceptual, in order to compare their influence on patients’ reasoning. Matching the patient and the control group on an established fluid reasoning test precluded potential misinterpretation that any differences in distractibility between the schizophrenia patients and the healthy controls might be explained in terms of intelligence differences. Finally, a perceptual conflict task was applied in order to measure the individual levels of distractibility to perceptual lures.

We expected that our schizophrenia patients would demonstrate significantly larger distractibility during analogical reasoning, despite having ample time to override distraction and revise responses; and that their reasoning on distraction-free analogies would be on par with reasoning of the controls. This prediction was rooted in patients’ observed proneness to making choices based on relatively little evidence, so called jumping to conclusion bias, and their lesser willingness to refine decisions in the face of new information (Averbeck et al., 2011; Evans et al., 2015; Fine et al., 2007; Rubio et al., 2011). Furthermore, there is a large body of research suggesting that context, which in the case of cognitive tasks is provided primarily by instruction, is ineffectively processed by schizophrenia patients (for review see Barch and Braver, 2005). According to the model proposed by Barch and Braver (2005), rooted in numerous prior studies (e.g. Barch et al., 2001; Braver et al., 1999; Servan-Schreiber, 1996), disturbances in context processing provide a common basis for deficits observed across multiple cognitive domains, including attention, inhibition, working memory, and language processing – all of them being essential for effective reasoning. Thus, we expected that our patients would fail to resist distraction in analogical reasoning, even when in principle they would have enough time to revise their responses.

In order to test whether this expected distractibility would be rooted in either semantic or perceptual processing. The former hypothesis would be supported by the strong impact of semantic distractors on schizophrenia patients’ reasoning, a lesser impact of categorical distractors (which mix the semantic and perceptual similarity), and the negligible role of perceptual distractors. Also, weak or no correlation between distractibility in the analogical reasoning task and the perceptual conflict task would be expected. By contrast, the latter hypothesis would be supported by the strong impact of perceptual distractors as well as a significant correlation between distractibility in the analogical reasoning task and the perceptual conflict task. That both these sources of distractibility might play a role was also considered. However, considering the reports on abnormalities in semantic processing (i.e., enhanced semantic priming) in schizophrenia (Moritz et al., 2001, 2003; for review see Pomarol-Clotet et al., 2008; Wang et al., 2011), the predominance of semantic distraction seemed more likely. The present study appears to be the most comprehensive examination of schizophrenia patients’ distractibility during complex cognition thus far.

1.1. Distractibility in analogical reasoning

Reasoning by analogy involves finding relational correspondence between two situations (analogs) and using it to transfer the knowledge from a more familiar situation (source) to a less familiar one (target) (Holyoak, 2012). For instance, if one has a basic knowledge about the Solar System (planets go around the sun), then one can make use of the analogy “an atom is like the Solar System” to infer the proper knowledge about the structure of atoms (electrons orbit around the nucleus). Both domains (the Solar System and atom) are very complex and can be described on many levels of detail. The reasoner thus needs to identify the key aspects of both domains in order to map together the corresponding relational structures, while ignoring those aspects that are irrelevant.

The presence of distraction in analogies has been addressed especially thoroughly in children samples. Young children encounter difficulties in conducting mapping that is driven solely by structural correspondence, when some perceptually similar or semantically associated objects compete for children’s attention (e.g. Gentner and Toupin, 1986; Richland et al., 2006; Starr et al., 2018). Children with low scores on the inhibition task were also reported to perform worse on analogies (Thibaut et al., 2011), suggesting that distractibility in relatively simple tasks might at least partly explain distractibility on a more complex level.

Research on clinical groups is much more scarce. For instance, Krawczyk et al. (2008, 2010) found that individuals with traumatic brain injury, who exhibit deficits in executive control, and patients with frontotemporal lobar degeneration, were less accurate in solving analogies when distractors were present. Crucially for the current topic, existing reports on distractibility during analogical reasoning in schizophrenia remain inconclusive (e.g. Krawczyk et al., 2014; Kucwaj and Chuderski, 2020), partially due to small sample sizes (from 13 to 30 patients) as well as the lack of group matching. The present study intended to fill this very gap.

2. Method and materials

2.1. Participants

Fifty-one inpatients diagnosed with schizophrenia according to the ICD-10 criteria participated in the study. At the time of participation, they had spent four to six weeks on the ward since being admitted to the hospital, and their condition was assessed as stable. All patients were being medicated with second-generation antipsychotics. All the patients were recruited from the general population through Internet adverts. The selection maximized the match between the control participants and the patients in scores on a subset of items from the hallmark Cattell Culture Fair Intelligence Test: ten items consisted of completing a sequence of drawings, and another ten items required picking one out of several geometric patterns that retained the relations between a number of figures as they were in the source picture. Sixteen minutes were allowed to complete these twenty test items. The selection of control
participants also minimized the group difference in age and sex structure. Table 1 presents descriptive statistics for the patient and the control group.

All the participants signed a written consent form to participate, were screened for normal or corrected-to-normal vision and no history of neurological disorders, and were informed that they could stop the experiment at any time. Each person was paid the equivalent of 7 euros in local currency. The entire procedure was approved by the local Ethics Committee.

### 2.2. Four-term analogies

The computerized task consisted of 30 four-term analogy problems having the format A:B::C:D, in which object D was absent. The participants were instructed to identify an analogy between the pair of objects according to a rule: A is to B, as C is to D, and to select D from seven response options presented below the problem. A, B, C, and the response options were pictures of simple common objects (e.g., apple, hammer, rabbit). The instruction included two problems (with and without distraction) with an explanation of the correct course of reasoning. The participants were informed that more than one object may seem to go with C, but they should choose the one and only object related to C in the same way as B is related to A. The instruction was followed by two training trials (one with and one without distraction). The feedback and the necessary explanations were provided during training. The participants could ask questions to the researcher in case of any doubts.

The participants responded by clicking a response option and confirming their choice using the “next” button. For each problem, the time limit was 20 s. Distractors were present among response options in 18 problems but were absent in another 12 problems. The order of problems was fully randomized across the task, so was the order of response options in each trial. All problems were selected from a larger bank of 40 problems, which had been carefully validated in a large sample (n = 471) of young, healthy adults (Kucwaj et al., 2021, 2022). All the stimuli were pictures of common objects; there were no two identical pictures within the entire item set.

In the distractor condition, the response options included: the correct response, the semantic distractor related to B, the categorical distractor related to B, the perceptual distractor related to B, the semantic distractor related to C, the categorical distractor related to C, and the perceptual distractor related to C. The perceptual distractor was defined as an object with a shape and color similar to B/C (e.g., a red billiard ball and a red tomato). The categorical distractor was defined as an object belonging to the same category and having a shape or color similar to B/C (e.g., a maple tree and a pine tree); in this case, the perceptual similarity was weaker than for the perceptual distractor. The semantic distractor was an object associated with B/C in terms of a shared domain, function, or occurrence (e.g., a bucket of paint and a paintbrush). In the non-distraction condition, there was the target and six unrelated objects in the set of response choices. Fig. 1 presents an exemplary item from the distraction condition.

### 2.3. Perceptual conflict task

Two words, one in black and one in red, were displayed in the middle of a computer screen. At the bottom of the screen, a row of four words was printed in gray. All words presented on the screen belonged to different semantic categories. The task was to click on a gray word identical to the black word as fast as possible. Participants were instructed to completely ignore the red word. In 20 non-conflict trials, the black and the red word were identical, thus leaving no room for distraction. In 30 conflict trials, the black and the red word were different, and a gray word identical to the red word (i.e., distractor) was included in the response set. The order of all 50 trials was fully random. The maximum response time was 3 s. Participants were provided with instruction and training (two trials without time pressure, four trials with time pressure). The individual score was the difference in mean reaction time between the conflict and the non-conflict trials. Larger scores indicated a larger proneness to perceptual conflict.

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**Table 1**

| Group description (range, mean ± SD in parentheses) | Schizophrenia group (N = 51) | Matched control group (N = 51) |
|-----------------------------------------------------|-----------------------------|-------------------------------|
| Age range in years                                  | 19–38 (29.18 ± 5.42)        | 18–38 (25.55 ± 5.51)         |
| Gender (no. of females)                             | 15                          | 32                            |
| Score range in Cattell's Culture Free Test (out of 20 items) | 6–16 (10.67 ± 2.27)         | 5–15 (10.31 ± 1.98)          |
| Number of years since the diagnosis                 | 0–19 (5.63 ± 4.72)          | N/A                           |
| Number of hospitalizations                          | 1–27 (6.35 ± 5.85)          | N/A                           |

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**Fig. 1.** Sample item of the Four-term Analogy in the distraction condition. The A:B::C:D? problem (top) is: puddle:rain boot:hot pot? Response options (bottom) are the following: an oven mitt is the correct response, a gas burner is a semantic distractor related to C, a frying pan is a categorical distractor related to C, an umbrella is a semantic distractor related to B, a boot is a categorical distractor related to B, chess pieces is a perceptual distractor related to B. The non-distraction condition included the target option and six unrelated objects as response options. The order of options was fully random across all trials in the study.
3. Results

3.1. Effects of group and distraction in four-term analogies

A repeated-measures ANOVA compared the performance in the distraction vs. the non-distraction condition of the schizophrenia patients vs. the matched healthy controls group (see Fig. 2). The main effect of the group was statistically significant, with higher accuracy of the controls, as compared to the patients ($\Delta M = 10\%$, $F(1, 100) = 19.41, p < .001$, $\eta^2 = 0.16$). The main effect of the condition was also significant, with higher accuracy in the non-distraction condition, as compared to the distractor condition ($\Delta M = 18\%$, $F(1, 100) = 138.08, p < .001$, $\eta^2 = 0.58$). However, the data pattern was significantly qualified by the interaction of the condition and the group factors, indicating that the drop in accuracy from the non-distactor to the distractor condition was significantly larger in the patients ($\Delta M = 25\%$, as compared to the controls ($\Delta M = 11\%$, $F(1, 100) = 19.71, p < .001$, $\eta^2 = 0.17$). Most importantly, the difference in accuracy between the patient ($M = 66\%$) and the control group ($M = 83\%$) was significant only in the distraction condition, $F(1, 100) = 25.04, p < .001$, $\eta^2 = 0.20$, while the patients ($M = 91\%$) were comparably accurate as the controls ($M = 95\%$) in the non-distraction condition, $p = .085$.

3.2. The pattern of errors in four-term analogies

To compare the pattern of errors between the groups we summed up the number of distractors of each type that were selected in each group. The first finding was that distractors to B (the sum of semantic, categorical, and perceptual response options) played a negligible role during analogy processing. In the control group, distractors to B were chosen only 5 times (out of 918 trials). In the patient group these distractors were chosen 31 times, but two participants, who generally demonstrated poor performance in the task, were responsible for 13 of these errors; the remaining patients committed 0, 1 or 2 errors (the latter committed by three participants) consisting of selecting a distractor to B. We concluded that object B served only to establish the relation between A and B, but once the relation was known, B was no longer considered during response selection. Therefore, only selection of distractors to C was analyzed further. Fig. 3 presents the selection rates for each distractor type, for the patients and the control group separately. Patients committed significantly more errors of each type as compared to the healthy controls, each $p < .03$, but there was no interaction of the error pattern and the group.

3.3. Performance in the perceptual conflict task

A repeated-measures ANOVA compared the reaction time in the distraction vs. the non-distraction condition of the schizophrenia patients vs. the matched healthy controls group. The main effect of the group was statistically significant, with shorter reaction time to the gray word displayed of the controls, as compared to the patients ($\Delta M = 225$ ms), $F(1, 100) = 28.08, p < .001$, $\eta^2 = 0.22$. The main effect of the condition was also significant, with shorter reaction time in the non-distractor condition, as compared to the distractor condition ($\Delta M = 79$ ms), $F(1, 100) = 46.29, p < .001$, $\eta^2 = 0.32$. However, the effect of interaction was not significant, $p = .527$.

3.4. The relationship between distractibility in four-term analogies and the perceptual conflict task

Distractibility in the perceptual conflict task was computed as the difference in reaction time between the conflict and the non-conflict condition. The mean difference equaled $M = 72$ ms ($SD = 109$ ms) in the schizophrenia group, and $M = 87$ ms ($SD = 127$ ms) in the control group. The difference between the groups was not significant, $p = .527$. Distractibility in Four-term Analogies was computed as the difference in accuracy between the non-distraction and the distraction condition. The mean difference equaled $M = 0.26$ ($SD = 0.16$) in the schizophrenia group, and $M = 0.11$ ($SD = 0.14$) in the control group. In both tasks, the trials in which no response was provided were discarded. The correlation between these two measures was not significant both in the patient group, $r = -0.002$, and in the control group, $r = -0.132$, each $p > .05$.

In the case of the patient group, there was no significant correlation between distractibility in Four-term Analogies and the number of hospitalizations, $r = 0.028$, or the number of years since the diagnosis, $r = -0.105$, $p > .05$. Likewise, there was no significant correlation between the two variables and the distractibility in the perceptual conflict task, $r = -0.167$ and $r = -0.086$, for the number of hospitalizations and the number of years since diagnosis, respectively, each $p > .05$.

4. Discussion

Schizophrenia patients and healthy controls, matched together according to intelligence, solved the A:B::C:D four-term analogies that

![Fig. 2](image-url) Mean accuracy in the non-distraction and the distraction condition of Four-term Analogies in the schizophrenia group and the control group. Bars indicate 95% confidence intervals for means.
either did or did not include the distractors. The distractors could be related to an element of the analogy problem (either B or C) in a semantic, categorical, or perceptual way. The two main research questions asked (1) whether the patients would display increased distractibility specifically (i.e., despite performing well on distraction-free analogies), and (2) whether this distractibility would involve selecting semantic (and categorical) distractors or rather it would involve perceptual distractors.

First of all, both the schizophrenia patients and the matched healthy controls were comparably highly accurate in analogical reasoning when distractors were absent. Furthermore, both groups yielded a significant drop in accuracy in the presence of distraction. At this point the group similarities end, because the patients’ reasoning was distractible to a significantly greater extent than that of the controls’ reasoning. These results suggest that schizophrenia patients are in general capable of effective analogy making but display a specific deficit in reasoning when some highly salient objects compete with the correct solution. Notably, the patients’ substantial drop in accuracy in the distraction condition did not result from their lower intelligence, because the groups were matched on the fluid reasoning test score.

Then, how to explain poor reasoning performance in the schizophrenia patients in the face of distraction? Both the patients and the controls were mostly distracted by semantic and categorical distractors to C, suggesting that both groups’ distractibility in analogies were driven by associations, either related to the shared function and context (semantic distractors) or shared properties (categorical distractors). Perceptual similarity (perceptual distractors) played a minor role. However, the tendency to be distracted by semantic similarity was particularly pronounced in schizophrenia patients. This may result from two dysfunctional mechanisms. First, as patients are more vulnerable to intrusive associations due to abnormalities of associative processing (Pomarol-Clotet et al., 2008; Wang et al., 2011), it is more likely that distractors quickly attract their attention. This mechanism has a relatively bottom-up character, as it is rapid and automatic (like priming). Second, once their attention is improperly attracted, patients can be less willing to question and verify intrusive responses, in line with aforementioned literature on jumping to conclusion bias (Averbeck et al., 2011; Evans et al., 2015; Fine et al., 2007; Rubio et al., 2011), as well as they can be less capable of revising their response due to ineffective context representation (Barch and Braver, 2005). These mechanisms are rather top-down, as they refer to evaluation of alternative response options.

In the case of the four-term analogies, context, provided by instructions, requires paying proper attention to the relation between A and B. Presumably, patients, similarly to children (Thibaut and French, 2016), ‘jump’ almost directly to C, neglecting the A-B pair, when in fact this pair carries the most crucial piece of information required to produce the correct analogy, instead of relying on simple associations. This faulty strategy can still be effective in the case of the no-distraction condition, as the correct response is the most salient of all the options, but such a strategy strongly impairs performance in the distraction condition.

Alongside the four-term analogies, we applied a simpler perceptual conflict task. Schizophrenia patients needed significantly more time to respond to words, as compared to the healthy controls, suggesting lower processing speed, which is in line with existing literature (e.g. Dickinson et al., 2007; Knowles et al., 2010). However, distractibility computed as the difference in reaction time between the conflict and the non-conflict condition did not differentiate between the groups. In other words, despite being slower than the healthy controls, patients were comparably affected by perceptual conflict, in contrast to their larger proneness to semantic conflict observed in the analogy task. Also, in both groups these two kinds of distractibility were unrelated, suggesting that they tap into different cognitive mechanisms.

It needs to be noted that existing findings on the increased priming effect in schizophrenia are based on latency analyses in relatively simple tasks (e.g. lexical decision task, semantic priming task). In order to verify that the abnormalities in semantic processing might also underlie increased distractibility during analogical reasoning, more sophisticated methods are necessary. For instance, eye-tracking would help to confirm whether patients’ attention is indeed instantly captured by semantic distractors and whether patients are less willing to analyze alternative options. The present study certainly paves the way for more advanced studies of distractibility mechanisms in schizophrenia. Lastly, in future studies it would be worth extending the battery of cognitive tasks as well as the symptoms assessment to gain deeper insight into cognitive correlates of distorted reasoning. Promising direction of investigation includes the assessment of formal thought disorder (FTD) as it was found to be related with decreased semantic inhibition (Martin et al., 2016).

5. Conclusion

This study improved our knowledge on distraction that hinders complex cognition in schizophrenia. Semantic distractors, but not perceptual distractors, affected analogical reasoning in both the healthy controls and the schizophrenia patients, but did so significantly more.
strongly in the case of the patients. By contrast, when distractors were absent, the patients’ performance was close to optimal. Therefore, deficits in complex cognition of schizophrenia patients seem to be primarily related to abnormalities in semantic processing, such as intrusive associations and weakened inhibition. Importantly, this effect must be related to dysfunctions of some specific mechanisms (to be revealed in future studies), as we ruled out the role of the patients’ deficits in general intelligence.

**CRediT authorship contribution statement**

All authors designed, conceptualized, and planned the study. H. Kucwaj and Z. Gajewski collected the data. H. Kucwaj and M. Ociepka undertook the statistical analysis. All authors contributed to and approved the final manuscript.

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**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.

**Appendix A. Supplementary data**

Data can be freely downloaded from https://osf.io/v96ft/

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