Modality-specific sensory norms: a new window into semantic organization[1]

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Abstract

In this chapter we will give a brief overview of the research that emphasized the importance of perceptual information in the structure and function of semantic knowledge. We will then describe a recently developed approach in operationalizing conceptual representations that relies on the relevance of perceptual information. The core of this approach builds upon word concreteness (the extent of perceptual experience with an object denoted by a word) and further elaborates it by estimating perceptual experience across separate sensory modalities (visual, auditory, tactile, olfactory, gustatory). We will summarize the data collected in several languages that converge to show the structure of perceptual space within the semantic system. Finally, we will propose to use this approach as a novel way of obtaining insights into the structure of the semantic systems of special populations. Here, we will focus on language of individuals with schizophrenia, but we will suggest that it can be used in general.

Key words: embodied cognition, perceptual experience, schizophrenia, semantic representations, word concreteness

1. Different approaches to semantic knowledge

The beginning of psychological research on the structure of semantic knowledge has been marked by numerous attempts to detect relevant semantic categories and relevant principles of classification. Early attempts viewed semantic knowledge as a hierarchical network of concepts, the topography of which was defined by the number of hierarchical levels (nodes) between the concepts (Collins & Quillian, 1969). The knowledge was structured in an encyclopedic way,

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by placing subordinate concepts under the node of the superior concept (e.g. *cat, mouse, lion* etc. under the node for *mammals*), and by propagating the features of the superior concept to all of the subordinates (e.g. *all mammals have fur*). Given that empirical data collided with multiple predictions from such a model, the hierarchical topography was replaced with a topography defined by similarity among concepts (Collins & Loftus, 1975). However, these models were not able to account for the fact that not all concepts could be classified into categories, and that not all categories have clear boundaries (McCloskey & Glucksberg, 1978). Therefore, the prototype theory was introduced (Rosch, 1973; Rosch & Mervis, 1975), which approached the semantic system in a different way. Within this approach, categories were organized around an abstract entity – the so-called prototype – which entailed all the features of the concepts within the given category, weighted by frequency of occurrence. Concepts were organized according to the level of typicality, i.e. similarity to this abstract category average. Although this model was able to account for more empirical data than its predecessors, it was not able to account for the fact that not all concepts have their prototype (Hampton, 1981), or for the human capability to form ad hoc categories (Barsalou, 1985), and it was not able to capture information on the variability within a category (Rips & Collins, 1993). In order to resolve these issues, exemplar theory was introduced (Nosofsky, 1988; 1991; Kruschke, 1992). According to this model, the concept is not defined by the abstract entity, but by all the exemplars that we have encountered which are stored in the memory. The relevance of the idea of the existence of a categorical organization in the semantic system has also been strengthened by neuropsychological and neuroimaging data. Multiple cases of category-based agnosia have been documented (Samson & Pillon, 2003; Shelton, Fouch, & Caramazza, 1998; Warrington & McCarthy, 1983; Warrington & Shallice, 1984), and numerous studies have identified brain areas that correspond to categories of objects (e.g. *houses, animals, fruits, tools* etc. Chao, Haxby, & Martin, 1999; Martin & Chao, 2001).

Simultaneously with describing relevant categories of concepts, attempts were made to specify relevant features that describe those (Cree & McRae, 2003). For example, Smith, Shoben, and Rips (1974) proposed the feature overlap theory, according to which concepts are stored in the form of the list of their defining features that are present in all category members and characteristic features that are specific to the given concept. The process of recognizing concepts and discriminating among them would rely on the process of feature comparison. Others have stressed the importance of perceptual (important for living things) versus functional (important for tools) features (Farah & McClelland, 1991; Warrington & Shallice, 1984). The relevance of features has also been documented in the profiles of neuropsychological patients (Lambon-Ralph, Howard, Nightingale, & Ellis, 1998), as well as in neuroimaging data (Goldberg, Perfetti,

& Schneider, 2006; Hauk, Johnsrude, & Pulvermuller, 2004), as will be discussed in more detail in section 2.

In addition to defining categories and features of concepts, attempts were made to understand whether conceptual representations should be defined in terms of analogue properties or in terms of abstract formal relations. Paivio (1971; 1991; 2013) advocated for the representational difference between concrete and abstract concepts (those that can and cannot be experienced perceptually; e.g. *apple* vs. *truth*). According to his dual-coding theory, all concepts are stored in so-called logogens (mental representations entailing various lexical characteristics), but concrete concepts have additional mental representations, so-called imagens, which entail analogue perceptual characteristics. On the other hand, Pylyshyn (1984, and also Anderson & Bower, 1973) argued that all concepts can be stored in terms of propositions – abstract relations among them, without the need to introduce analogue code in order to store the semantic knowledge. The view that perceptual information is not relevant for the organization of the conceptual system was shared by others (Fodor, 1975; Smith & Medin, 1981; Tulving, 1972). More recently, other theories were proposed to account for the observed differences between concrete and abstract concepts. For example, context availability theory (Schwanenflugel, Akin, & Luh, 1992) attributes concreteness effects to the stronger and richer associations of contextual knowledge (both in terms of discourse and relations to other language items).

The ideas originally proposed by Paivio (1971; 1991; 2013) were revived within the embodied cognition accounts that have gained popularity during the last decades, especially within the perceptual symbol theory (Barsalou, 1999). According to this theory, mental representations are traces of perceptual experiences and reside within the same system with the perception states that produced them. The activation of the mental representation is based on the re-activation of the same neural pathways that were involved in the perception of the given entity. Therefore, visual aspects of the mental representation of an object should be located in brain areas involved in visual perception, auditory aspect in brain areas involved in auditory perception, and so on.

2. The embodied approach to semantic knowledge

2.1. The importance of perceptual information

In the past decades, numerous studies were dedicated to testing for the relevance of the perceptual information in the concept representation (Barsalou, 1999; Barrós-Loscertales et al., 2012; Goldberg, Peretti & Schneider, 2006a; 2006b; González, et al., 2006; Kiefer, Sim, Herrnberger, Grothe & Hoenig, 2008; Pecher, Zeelenberg & Barsalou, 2003; Pulvermüller, 2005; Simons, et al., 2007). Goldberg and colleagues (Goldberg et al., 2006b) conducted an fMRI study in which participants were scanned during a property verification task. The participants had to respond whether a concrete word (i.e. an object denoted by that word) possessed one of the four modality-specific perceptual properties: colour, sound, touch, or taste (for example, *Is an apple green?*). They aimed to find which brain regions were engaged in the encoding of modality-specific perceptual information. The results supported a multi-modal view: the sensory experiences of an object and the decision about its perceptual property seem to share common neural activations. For instance, retrieval of the tactile knowledge of an object was related to increased activation in the somatosensory cortex, motor and premotor brain regions. Furthermore, taste knowledge provoked increased activity in the orbitofrontal cortex, the region that had been previously found to be associated with the semantic categories, such as the category of food, for which the taste information is essential (Goldberg et al., 2006a). In a similar manner, auditory knowledge was linked with increased activity located in the left superior temporal sulcus, inferior and posterior to the primary auditory cortex, whereas visual knowledge evoked ventral parts of the left temporal cortex, an area involved in the generation of color information of objects. The relevance of the color and motor properties of objects and their modality-specific brain representations was demonstrated by Simmons and his colleagues (Simmons et al., 2007). They applied two different tasks during the fMRI scanning: a property verification task and a color perception functional localizer task. In the property verification task, the concept followed by the property (*banana* followed by *yellow*) were presented and the participants had to decide whether the property is true for the concept or not. In the later phase, only the concept was presented, without the property, in order to apply subtraction and to see which neural parts are active during the processing of conceptual properties. With this task, researchers wanted to explore the conceptual representations of color and motion, whereas the color perception functional localizer task was applied to provide insight into the brain region activations during color perception. In the color functional localizer task, participants were instructed to judge whether the five color or grayscale widgets are ordered by hue – from lightest to darkest. This study design provided a simultaneous comparison of brain area activations during conceptual processing and during perceptual processing within the same participant. Results showed that both conceptual and perceptual processing provoked stronger activity in the left fusiform gyrus. Contrary to this, verification of the motor properties of an object resulted in increased activity in the left middle temporal gyrus, the area for which previous studies showed to be evoked during observation of motions (for example, Beauchamp, Lee, Haxby, & Martin, 2002). Associations of auditory object features with brain regions that are active during auditory perception are also well documented in the literature. In one such study, the authors, who were motivated to unambiguously determine that concepts are grounded in perception, combined conceptual and perceptual tasks with both fMRI and ERP imaging techniques (Kiefer et al., 2008). They advocated that conceptual grounding could be demonstrated only if conceptual processing during the implicit task could activate rapidly a complementary perceptual brain region. In other words, in order to make such claim, the activation of brain areas which does not occur as a consequence of mental imagery should be demonstrated. The inclusion of ERP enabled researchers to determine the timeline of brain region activations during the course of conceptual processing. They found that, during the lexical decision task, the words with acoustic conceptual features (e.g., *telephone*) provoked stronger activity in left posterior superior and middle temporal gyrus compared to words without acoustic conceptual features (e.g., *flower*). The processing of sounds elicited activation in the same posterior temporal area. Moreover, ERP recordings showed that these activations occurred early in the conceptual processing (at 150ms after a word's onset), thus without the engagement of auditory imagery (Kiefer et al., 2008). Activations of olfactory brain regions during the reading of words with strong olfactory associations were demonstrated as well (Gonzales et al., 2006). In that study, reading words such as *garlic* or *cinnamon*, compared to olfactory neutral words, elicited bilateral activations in primary olfactory areas and the right amygdala, the brain regions that are active during the processing of real smells. The grounding of gustatory conceptual associations was revealed in one recent study (Barrós-Loscertales et al., 2012). The authors found increased activation of the primary and secondary gustatory brain regions, responsible for gustatory perception, during the reading of words strongly associated with the gustatory modality (for instance, *salt*). Those words were matched for a large number of lexical attributes, namely, arousal, emotional valence, imageability, frequency of use, and number of letters and syllables, in order to exclude possible lexical explanations.

2.2. Modality-specific sensory norms

The first variable that was linked to the relevance of perceptual information was word concreteness, as popularized by Paivio (1971; 1991; 2013; but also mentioned in Woodworth & Schlosberg, 1954). It was operationalized as the extent of sensory experience with an object (phenomenon, feature, and action) denoted by a given word (Brysbaert, Warriner, & Kuperman, 2014; Brysbaert, Stevens, De Deyne, Voorspoels, & Storms, 2014; Ćirić & Filipović Đurđević, 2017; Paivio, Yuille, & Madigan, 1968). It was typically measured on a bipolar scale with one end denoting abstract words (i.e. words that denote objects that cannot be experienced perceptually, e.g. *truth*, *justice*), and the other end denoting concrete words (i.e. words that denote objects that can be perceptually experienced, e.g. *apple*, *chair*).

Lately, word concreteness has been elaborated further and a novel operationalization has been proposed (Connell & Lynott, 2012; Filipović Đurđević, Popović Stijačić, & Karapandžić, 2016; Popović Stijačić & Filipović Đurđević, in preparation; Lynott & Connell, 2009; 2013; Miklashevsky, 2018; Speed & Majid, 2017). Instead of collecting one rating of general perceptual experience with an object, the separate ratings are collected for each sensory modality. Participants are presented with a task to rate the extent to which they were able to experience the object denoted by a given word in visual, auditory, tactile, olfactory, and gustatory modality, i.e. to rate (on separate scales) the extent to which they were able to see, hear, touch, taste, and smell an object denoted by a given word. Additionally, in order to test for the relevance of the real experience with an object, as opposed to the rated possibility of experiencing it (for example, we could touch the moon, but only a few people have actually done so), authors of the Serbian norms proposed two rating instructions: one that was related to possible experience (to what extent is it possible to experience the concept through the particular perceptual modality) and the other that was related to real experience (to what extent the concept was actually experienced with the specific sense). This distinction between rating instructions should contribute to the theoretical distinction between "weak" and "strong" embodiment theories (Meteyard, Cuadrado, Bahrimi & Vigliocco, 2012). For example, strong embodiment theories emphasize the relevance of perceptual experience with an object and the activation of primary cortical areas in semantic processing. Therefore, the predictive advantage of the sensory ratings based on the real experience with an object over the sensory ratings based on the possible experience with the same object would advance this point of view.

The data on modality-specific sensory experience which have been collected in several languages seem to converge in multiple ways. For example, within the space of perceptual variables, the strongest associations were recorded for gustatory-olfactory and visual-haptic modalities, whereas auditory modality showed a distinct relational pattern. In other words, auditory perceptual modality had either negative or zero correlations with other perceptual modalities (Lynott & Connell, 2013; Filipović Đurđević et al., 2016; Popović Stijačić & Filipović Đurđević, in preparation; Miklashevsky, 2018; Speed & Majid, 2017). Furthermore, the principal component analysis in most cases converged into two components, one which was saturated with visual and haptic modality ratings, and another that was loaded with olfactory and gustatory ratings (Speed & Majid, 2017; Miklashevsky, 2018; Popović Stijačić & Filipović Đurđević, in preparation). The analysis of correlations with word concreteness revealed that majority of modality specific ratings had positive correlations with this variable. Positive associations with concreteness were registered for visual, gustatory, olfactory, and tactile modality, whereas auditory modality and concreteness had negative and/or zero correlations.

The contribution of normative studies is reflected in one additional aspect. Connell and Lynott (2012) and Filipović Đurđević et al. (2016) advanced several integrative measures of perceptual richness as a more suitable measure of perceptual experience compared to concreteness. Some of these measures are suggested as ones expressing the intensity of perceptual experience (maximal perceptual strength & modality exclusivity; Connell & Lynott, 2012); others, as a way of capturing variability and multimodality (entropy, number of modalities; Popović Stijačić & Filipović Đurđević, 2015; Filipović Đurđević et al., 2016), and there are measures which are constructed to quantify both the intensity and multimodality of the perceptual experience (summed perceptual strength and vector length; Filipović Đurđević et al., 2016). Maximum perceptual strength represents the maximal mean value recorded on one of the five modality-specific perceptual strength scales (Lynott & Connell, 2012), thus it is the most comparable to traditional concreteness among other perceptual richness measures. Modality exclusivity is computed as the ratio of the range of five modality-specific perceptual strength ratings and their sum; accordingly, the largest value is assigned to a word that has high values on one modality rating and low values on the others, whereas lower values are specified for those words that have high saturation on each of the five perceptual strength scales (Connell & Lynott, 2009). The lowest possible value (0) is assigned to words with no variability in ratings. However, in this case (if the ratings are equal across modalities), this measure does not differentiate between words that can be fully experienced in all modalities (all mean ratings have maximum value) and words that cannot be experienced in any modality (all mean ratings have the minimum value). In order to remedy this situation, Filipović Đurđević et al. (2016) proposed entropy as the measure of variability across modalities. The number of modalities is defined as the number of perceptual modalities through which a concept could be experienced (Popović Stijačić & Filipović Đurđević, 2015; Filipović Đurđević et al., 2016), while the summed perceptual strength is calculated as the sum of the averaged scores on each modality-specific perceptual strength scale. Finally, the vector length is operationalized as the Euclidean distance of the vector from the zero point (Connell & Lynott, 2012). In other words, it represents a five-element vector, and it is more informative than summed perceptual strength, although essentially it captures highly similar information.

The relevance of these measures for language processing was validated in language processing tasks. For example, in a Serbian norming study (Filipović Đurđević et al., 2016), all perceptual modalities significantly predicted response latencies in a lexical decision task, after controlling for concreteness, word length and lemma frequencies. In other words, an increase in modality-specific perceptual strength was accompanied by a decrease in reaction times, with the exception of auditory modality, which was not predictive of the processing latencies. When it comes to integrative measures of perceptual diversity, the results have not yet fully converged. In a British study (Connell & Lynott, 2012), the maximum perceptual strength outperformed word concreteness and imageability in lexical decision tasks. However, in a Serbian study (Filipović Đurđević, et al., 2016), the predictive power of concreteness was outperformed by summed perceptual strength, vector length, and entropy. In other words, these results suggested that both the strength and the variability of the perceptual experience facilitate word recognition. Finally, results have revealed that in predicting processing latencies, integrative measures based on the ratings of real experience outperform the measures based on the ratings of possibility to experience.

3. The application of modality-specific sensory norms to the language of special populations

We have focused on the relevance of perceptual experience to illustrate the embodied approach to cognition (although it includes other bodily experiences as well, such as motor and emotional experience). We would like to argue that the embodied cognition approach which has dominantly been applied to investigating the language of healthy speakers can also be a useful tool for understanding impaired language. We believe that this approach has the potential to be applied to a wide spectrum of disorders. However, given that the topic of the meeting which inspired the current volume was the language of the individuals with schizophrenia, we will focus here on this specific population. We will start by briefly introducing the peculiarities of language in schizophrenia and continue by illustrating the application of the approach in question to this particular population.

3.1 Relevant topics on language and schizophrenia

Schizophrenia is a mental disorder that usually becomes apparent in young adulthood and is clinically described via a set of heterogeneous symptoms (American Psychiatric Association, 2000). It affects states and functionality in the cognitive, affective, and motivational domains and is typically described in terms of positive and negative symptoms. Positive symptoms refer to the presence of states and behaviors that are not present in the typical population, such as hallucinations, delusions, or disorganized language output. Negative symptoms refer to the absence of states and behaviors that are present in typical population, such as lack of motivation, flat emotions, or poverty of speech.

When it comes to language, individuals with schizophrenia manifest both negative and positive symptoms. Negative symptoms are usually characterized by the poor language output, whereas positive symptoms come in several different forms. As Kuperberg (2010a) summarized, positive thought disorder, which is closely linked to positive language symptoms can include "derailment" (spontaneous speech that starts as related to the topic but slips into speech that is partly or completely unrelated to it), or "tangentiality" (responsive speech that is irrelevant to the question which initiated it), whereas both of them could be described as "loosening of associations" (Kuperberg, 2010a, p3). These disorders are related to the level of the sentence and discourse, and in fact, they represent the most common language disorders in patients with schizophrenia. However, there are also symptoms related to the level of the single word (e.g. neologisms, idiosyncrasies in word meanings etc.). According to Kuperberg (2010a), statistical analyses of the speech output of individuals with schizophrenia showed that their words were less predictable as compared to the speech of control participants, characterized by weaker and less restricted lexical associations, and that they produced fewer different words relative to the total number of words produced (as expressed by the Type:Token ratio). Additionally, at the level of lexical and syntactic structure, their words were more related to the previous word than to the topic, and their sentences were less complex and more grammatically deviant. Finally, at the level of the discourse, their cohesion devices were linking the speech with real-word referents and previous referents in a manner that was less specific, less informative, and less relevant.

When it comes to theoretical attempts at understanding language disorders in schizophrenia, two main streams have been identified. According to Kuperberg (2010a), one theoretical stream attributes language disorders in schizophrenia to abnormalities in the structure and function of semantic memory. The other stream focuses on working memory, especially executive function deficits which, according to this view, lead to problems in adequate use of context and consequently bring about language dysfunction. On the one hand, semantic/associative priming in schizophrenia seems to be augmented in tasks that favor automatic processes, whereas it seems to be attenuated in tasks that favor strategic processing (Pomarol-Clotet, Oh, Laws, & McKenna, 2008). Kuperberg, Deckersbach, Holt, Goff, and West (2007) linked this asymmetry to the asymmetry of activation in the fronto-temporal network. They observed reversed neural priming (increased activation to associated targets) in the fronto-temporal cortices of individuals with schizophrenia, with particularly increased activation in the temporal cortex of individuals with positive thought disorder. They interpreted this as a sign of reduced efficiency of the inferior prefrontal cortex in controlling strategic lexico-semantic retrieval (selection of semantic representations stored in the temporal cortex), and increased residual activation in the temporal cortex which occurred consequently (this activation occurs automatically but is typically controlled by a functional prefrontal cortex; see also Kuperberg, Delaney-Busch, Fanucci, & Blackford, 2018). On the other hand, the performance of individuals with schizophrenia on working memory and executive function tasks is severely degraded. Multiple research has established an association between the level of decline in executive functioning, on the one hand (as tested by the Stroop task, tasks of sustained attention, sequencing, distractibility, etc.), and thought disorders, on the other hand (Kerns, 2007). Some studies even determined a link between executive functioning and errors in referential communication (Docherty, 2005). However, although the link between schizophrenia and executive function deficits has clearly been established, not many studies have been aimed at determining a link between executive function deficits in schizophrenia and language disorders in schizophrenia. The results of studies that investigated sentence processing in individuals with schizophrenia suggested that it was more driven by lexical-semantic relations, and that these individuals were less likely than controls to use the context in constructing interpretation (as reviewed by Kuperberg, 2010b).

3.2. A proposal of a novel approach to language in schizophrenia

Numerous studies have unequivocally established that multiple cognitive functions are deficient in schizophrenia (Kuperberg, 2010a). Few would object that individuals with schizophrenia suffer from some kind of disturbances which arise at the interplay of the changed semantic associations and compromised working memory functions. At the same time, not everybody agrees as to what represents the core deficit, and what appears only as its consequence (Zaytseva et al, 2018). However, in this chapter, we want to draw attention to the possibility of taking a completely different point of view, and doing so with completely different tools.

3.2.1. The rationale

We would like to focus on the preserved aspects of cognitive functioning, namely the preserved structure of the semantic system. We believe that, in order to be able to fully understand a deficit, one must clearly establish not only what is damaged, but also what is preserved. In terms of semantics, it has been widely investigated and determined that language in schizophrenia is characterized by loosened associations among concepts (Kuperberg, 2010a). However, to the best of our knowledge, there have been no inquiries into the nature of representations beyond their position in relation to other concepts. Here, we propose to focus on perceptually relevant conceptual representation in individuals with schizophrenia in order to determine whether it is comparable to that of a control population. If it were comparable, the finding would serve as the starting point of knowing what is preserved in the semantic system, and further investigation should be directed towards higher levels in the language hierarchy (phrases, sentences, discourse, etc). If it were altered, the findings would bring novel insights into the language of this specific population. Once the link has been established between the structure of the perceptual-semantic system and schizophrenia, this finding could help differentiate the diagnosis during the first psychotic episodes, or even prior to the onset of symptoms in populations under risk. Some research has already suggested the existence of specific characteristics in the language system of individuals who belong to families with an identified risk of schizophrenia (Thermenos, et al., 2013). Similarly, it has been shown that the structure of the semantic system can be informative of the risk of developing schizophrenia (Tonelli, 2014).

At the same time, we would argue that insights into the level of preservation of the semantic system in schizophrenia would also be informative for theories of the semantic system in the general population. For example, there is an ongoing debate on whether semantic representations are stored in the temporal cortex. On the one hand, there is a view that the left temporal cortex (along with the left inferior parietal cortex) stores not only phonological and syntactic knowledge, but also semantic word knowledge (Hagoort, 2005, 2014). Similarly, there are claims that posterior temporal regions serve to control semantic representations that are stored in the anterior temporal lobe (Jefferies, 2013; Noonan, Jefferies, Visser, & Lambon Ralph, 2013; Ralph, Jefferies, Patterson, & Rogers, 2016). On the other hand, there are views that the temporal cortex does not serve as the store of the semantic word knowledge (Hickok & Poeppel, 2004, 2007, 2015). According to this view, the temporal cortex provides the mappings of sound to meaning, whereas meaning is distributed widely across different cortical areas. We believe that insight from research on the semantic system in schizophrenia could inform this important debate. On the one hand, we advocate for the exploration of the structure of perceptual space of individuals with schizophrenia. According to embodied cognition views (Barsalou, 1999), perceptual space (which is neurally based in cortical sensory areas) homes the knowledge of word meanings. On the other hand, it has been known that the functioning of the temporal lobes is changed in schizophrenia (Lawrie et al., 2002; Turetsky et al., 1995). Therefore, a finding that the structure of perceptual space is intact in schizophrenia would strengthen the views that semantic knowledge is distributed.

Additionally, the approach that we are advocating would contribute to the efforts of disentangling language-specific processes from those related to executive functions. For example, one of the most frequently administered tests to assess cognitive functioning in individuals with schizophrenia is the verbal fluency task. As this task taps both into language and the executive functioning (Aita, et al., 2018; Whiteside, et al., 2015), the researchers typically applied two versions of this task – phonemic fluency and semantic fluency to try to disentangle the impairment that could be attributed purely to the challenged executive functioning from that of the challenged semantic system. As reviewed by Henry and Crawford (2005), the level of impairment seems to be larger for the semantic fluency task, thus suggesting impairment to the semantic system, and not only to the executive functions. We suggest that this issue be approached by taking advantage of the attested empirical effects that have been previously observed in the healthy population and interpreted in light of the embodied cognition approach. Such effects are believed to arise as a consequence of the structure of the semantic system and have not been shown to be influenced by executive functions.

3.2.2. The proposed strategy

We therefore propose to start with two lines of research. The first line of research would address the structure of the semantic system as rooted in the modality specific perceptual information. The first step would be to collect modality specific sensory norms from individuals with schizophrenia, following the methodology that has already been applied in control populations (Connell & Lynott, 2012; Filipović Đurđević, Popović Stijačić, & Karapandžić, 2016; Popović Stijačić & Filipović Đurđević, in preparation; Lynott & Connell, 2009; 2013; Miklashevsky, 2018; Speed & Majid, 2017), while adapting it to the cognitive functioning of the participants from the special population. For example, instead of administering bipolar Likert scales to collect ratings, we suggest using simple yes–no questions (e.g. *Can a strawberry be tasted? Have you ever tasted a strawberry?*). This change in the procedure would make the task easier to administer and less demanding for the participants, who are often under medication or face hardship in complying to the complicated task requests. At the same time, it would not jeopardize the reliability of the collected data, given that there is a body of research in linguistics showing that yes–no questions and Likert scales provide converging data (Bader & Häussler 2010; Fukuda, Goodall, Michel, & Beecher 2012; Weskott & Fanselow 2011). Statistical analyses performed on these ratings would enable insight into the structure of semantics, namely the structure of the perceptual space in schizophrenia, and the comparison of this structure to the structure observed in the control population. The preserved structure of the modality specific perceptual information, i.e. the one that is comparable to that of healthy speakers, would inform us of what is preserved in the semantic system and direct the research towards other aspects of language in schizophrenia, while also strengthening the view that semantic word knowledge is distributed across sensory cortical areas, as discussed earlier (in 3.2.1.). The altered structure of the modality specific perceptual information (i.e. the one that is different from that of healthy speakers) would be particularly informative, as it would show, for the first time, that sensory specific perceptual space is different in schizophrenia. This novel finding would indicate that individuals with schizophrenia code their world knowledge differently, hence further research would be necessary to understand the dimensions of the newly discovered semantic space. Such understanding would enable both more efficient diagnostics and therapy. Although novel, such a discovery would not be overly surprising given the findings that show deficiencies in sensory processing in schizophrenia (e.g. as described in Tschacher, Giersch, & Friston, 2017).

The second line of research would further focus on the disentangling of language-specific (and also semantics-specific) processes from processes that are related to executive functioning. It would build upon the collected normative data to compare the healthy population and the population with schizophrenia, with respect to attested empirical effects that rely on the usage of interconnected perceptual information and demonstrate the relevance of perceptual information for language processing (Filipović Đurđević et al., 2016; Goldberg et al, 2006a; 2006b; Simons et al, 2007; Lynott & Connell, 2013; Živanović & Filipović Đurđević, 2011). For example, the integrative measures of perceptual richness (as discussed in 2.2.) could be introduced as predictors of processing latencies of individuals with schizophrenia (i.e. in the lexical decision task). This would allow for the investigation of efficacy in the use of perceptual information. Research with healthy participants showed that speakers make use of the rich perceptual traces of previous experiences with an object denoted by the word while performing word recognition (Lynott & Connell, 2013; Filipović Đurđević et al., 2016). Similarly, healthy speakers take advantage of the matching (congruence) of the modalities of the channels through which they obtain information (e.g. incoming information and stored knowledge). For example, they are faster at recognizing spoken words which denote an object that can be experienced by hearing (e.g. *chirp*) and printed words which denote object that can be experienced by vision (e.g. *sky*; Živanović & Filipović Đurđević, 2011). Similarly, they are faster if consecutive information arrives within the same channel than when the channel switches modality (Pecher, Zeelenberg, & Barsalou, 2003). Based on some previous insight, there is reason to expect that individuals with schizophrenia would fail to take advantage of perceptual richness during word recognition, as well as of the overlap between the channels of available information. For example, there are findings that schizophrenia is characterized by a lack of connectivity among sensory experiences and even elaborations on how this could lead to other symptoms: "Sensory processing would be fragmented, which might affect the patient's ability to feel as being immersed in the world, and to experience themselves as one single and continuing entity." (Tschacher, Giersch, & Friston, 2017, p. 749). Within such an approach, schizophrenia is seen as the case of disembodiment: "The resulting lack of intermodal integration could result in an impaired development of the embodied or 'ecological self' and its perceptual, cognitive and emotional ties with the environment." (Fuchs & Schlimme, 2009, p. 573). Such disembodied cognition would be manifested in a state of being overwhelmed by details without being able to grasp their meaningfulness or their relation to the context and consequently lead to detachment from the continuity of self and the environment.

4. Conclusion

We have briefly reviewed the main approaches to the understanding of semantic knowledge and particularly focused on the approach that views mental representations as enactments of the processes that were involved during perception. We have summarized the group of empirical findings that demonstrate the importance of perceptual information in language processing and in memory, suggesting that an important part of semantic knowledge is widely distributed in different cortical areas, namely in the areas that are involved in the processing of the relevant sensory information. We have also described a novel approach to describing word meaning in the form of profiles of sensory experience across different sensory modalities. Finally, we have suggested that this approach be used as a tool to investigate the language of impaired populations and illustrated our proposal by focusing on the case of schizophrenia. We looked into the typical issues in language processing in schizophrenia and proposed to apply both modality specific sensory ratings and various phenomena related to the importance of perceptual information in order to gain a better understanding not only of the language of individuals with schizophrenia, but also of the language of other special populations.

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