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Evaluating the Sensory Sensitivity of Individuals with High Intellectual Potential Using a Lexical Decision Task

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Abstract

Our study tested the hypothesis of hyperesthesia in people with High Intellectual Potential (HIP), reported in clinical observations. A group of HIP participants (N= 17) and a no-HIP group (n-HIP =17), matched on age and sex, were asked to complete a lexical decision task, consisting of weak and strong sensory words drawn from earlier work (Bonin, Méot, Ferrand & Bugaïska, 2015). Consistent with the literature, our results show that lexical decision times are shorter for strong, compared to weak sensory words. A further analysis of mean response times for strong and weak words highlighted that the HIP group was more sensitive to weak sensory words than the n-HIP group. These results support the argument that HIP individuals have heightened sensory sensitivity.

Keywords: High Intellectual Potential, Lexical Decision, Sensoriality, Embodied Cognition

Introduction

The aim of our work is to contribute to the understanding of intelligence. We adopt an original, ecological approach, namely embodied and situated cognition (Barsalou, 2008; Briglia, Servajean, Michalland, Brunel & Brouillet, 2017; Brunel, Labeye, Lesourd & Versace, 2009; Glenberg, 1997; Glenberg, 2000; Pecher, Zeelenberg & Barsalou, 2003; Pecher and Zwaan, 2005; Versace, Brouillet & Vallet, 2018; Zwaan, 2015). The latter considers that human cognition results from sensory-motor interactions between the individual and his or her environment. The key question is the emergence of intelligence, and its processes, as a product of the combination of intrinsic individual capacities and the specific environment of the subject. It requires the exploration of potential links between sensoriality and intelligence or, more precisely, between the capacity for perception and the processing of sensory information, and the intellectual capacities of individuals. The APA Dictionary of Psychology defines intelligence as: "*the ability to derive information, learn from experience, adapt to the environment, understand, and correctly utilize thought and reason"*. As early as 1910, Binet (p. 118) described "*understanding, invention, direction and censorship*" as the essential functions from which intelligence would emerge. Later, Huteau and Lautrey (2003) would note that the notion of intelligence must be understood as a capacity to adapt to new situations, and to engage in processes of understanding, knowledge and learning. Intelligence requires a minimum capacity for abstraction, automatic inhibition and inhibitory control. It refers to logic, cognitive flexibility, decision-making and creativity, but also to memory capacities that support learning, and the transfer and generalisation of acquired knowledge and skills. Grégoire (2009) compares it to a symphony; intelligence presupposes the involvement and concomitant exercise of all cognitive processes which, like experienced musicians, will produce notes that would not otherwise exist if all of the instruments had not been working in harmony, driven by the musicians' actions and intentions, working together. Nevertheless, as Neisser et al. (1996) pointed out, there is no universally accepted understanding of intelligence, and we still lack a comprehensive definition.

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However, the existence of individuals with cognitive skills that are far, or very far, above average is now widely accepted. These so-called High Intellectual Potential (HIP), or gifted individuals can now be identified using Weschler scales (WPPSI IV, WISC V, WAIS IV) that can identify individuals with a Total Intellectual Quotient (i.e., TIQ) of over 130. This quantitative, scored, measure of intelligence raises the question of what it tells us about the intelligence of an individual. While it reflects a set of cognitive skills in the person who is evaluated, it does not tell us much about the plurality of forms of expression of his or her intelligence (Renzulli, 2006). Furthermore, it is not representative of the abilities of a HIP individual, in particular the high creative-productive potential described by Renzulli (2006). Here, we adopt the definition of creativity given by Lubart (2012, p. 14) which is, "*the ability to produce something that is new and, at the same time, adapted to the context in which it occurs*".

Researchers have been particularly interested in this aspect of HIP. One example is the study by Ziegler and Raul (2000), which shows that it is one of five factors regularly associated with giftedness. The archetypal HIP child, drawn from several studies and proposed by Lubart et al. (2016, p.15) highlights a richness of thought that contributes to "*creativity, imagination and mental flexibility*". In the same vein, Naglieri and Kaufman (2001) point out that the identification of a HIP individual would be enriched by a complementary tool, the Cognitive Assessment System, which also evaluates the processes involved in creativity.

In addition to intellectual skills and creativity, it would appear that a person with HIP is characterised by what Dabrowski called overexcitability. The latter manifests as, "*an above-average receptivity to stimuli, manifested either by psychomotor, sensual, emotional (affective), imaginative, or intellectual responsiveness or a combination of these*" (Dabrowski, 1972, p. 303 cited in Mendaglio and Tillier, 2006, p. 69 and Winkler and Voight, 2016, p. 243). Piechowski (1979) goes on to propose a model of giftedness that is based on developmental potential derived from Dabrowski's theory, which focuses on *overexcitabilities* that are particularly notable in gifted and creative personalities. On a clinical level, the work of Siaud-Facchin (2008) and Revol (2015) appears to support the hypothesis of sensory hyperreactivity. In relation to our study, the latter authors reported greater perception of the physical characteristics of sensory stimuli in a HIP subject, a phenomenon that was named *hyperesthesia* by Siaud-Facchin (2008). Thus, the HIP subject is endowed with visual, auditory, olfactory, gustatory and kinaesthetic abilities that are consistent with sensory perceptions that are far above the average.

In this context, the aim of our work is to provide a better understanding of intelligence, notably through the study of sensorial hypersensitivity in subjects with HIP using the paradigm of embodied and situated cognition.

Throughout their life, an individual is constantly constructing and interacting with his or her environment. Näätänen, Astikainen, Ruusuvirta and Huotilainen (2010) report the simultaneity between auditory sensory perception and the production of automatic cognitive processes. In relation to intelligence, Raz, Willerman and Yama (1987) showed that the ability to discriminate sounds and cognitive skills were correlated. Deary (2004) confirmed this correlation in two experiments. In the first, the author gave adolescents three sensory discrimination tests (regarding colour, sound, and weight) and various cognitive ability tests (the Mill Hill Vocabulary Test, the Cattell Culture Fair Intelligence Test, and the Digit Symbol Test). They found correlations between: 1) scores obtained on the visual discrimination test and the Cattell and Digit Symbol tests; and 2) scores obtained on the auditory discrimination test and scores for all three intelligence tests. In their second experiment, the authors used data from Acton and Schroeder (2001), in which participants aged 13 to 62 (N = 899) completed three sensory tests (colour, sound, and fine motor skills), and 13 psychometric tests. They found a .68 correlation between general intelligence and scores on sensory test.

Finally, the study conducted by Melnick, Harrison, Park, Bennetto and Tadin (2013) on the ability of the HIP subject to discriminate between moving visual stimuli of different sizes provides further support for the exploration of the relationship between the physical and sensory environment, perception and cognitive processing in the HIP subject.

The aim of our study was to show, using the lexical decision paradigm (Meyer & Schvaneveldt, 1971)that the HIP subject is more sensitive than a non-HIP (n-HIP) to the underlying sensory dimension of words. Using the lexical decision paradigm to investigate the sensory sensitivity of HIPs has been highlighted, in particular, by work that takes an embodied approach to cognition. According to this approach, "*[...] understanding language calls on bodily states involved in perception, imagery, and action*" (Glenberg, Havas, Becker & Rinck, 2005, p. 118), and reading linguistic stimuli automatically activates the sensory dimensions that underlie the words they represent. This activation operates through a process of mental simulation.

Barsalou (2008) argues that mental simulation is the product of an interaction between the body, word and mind that leads to the reconstitution of the different states experienced during this interaction (i.e. introspective, perceptive and motor states). Zwaan (2004) calls these states "experiential traces". An extensive body of literature supports this point of view (for a discussion see Zwaan & Pecher, 2012; Zwaan, 2014; Zwaan, 2016). Moreover, the work of Juhasz, Yap, Dicke, Taylor and Gullick (2011), Juhasz and Yap (2013), and Bonin Méot, Ferrand and Bugaïska (2015) confirms the facilitating influence of the sensory dimension of words: words with a high Sensory Experience Rating (SER) are consistent with significantly shorter response times than words with a low SER. Thus, in our lexical decision task, we manipulated the sensory dimension of words, by presenting participants with items that operationalized two modalities: weak sensory words and strong sensory words. All words used in our study were drawn from the study by Bonin et al. (2015), in which participants (N = 131) were asked to give a sensory experience score to French words on a Likert scale ranging from 1 to 7.

We hypothesised that if people with HIP have greater sensory sensitivity compared to n-HIP people, then the former should be more sensitive to sensory variation in words than n-HIP people. We therefore predicted that strong sensory words would be evaluated more quickly than weak sensory words, especially by HIP participants.

Method

Participants

Our 34 participants (20 men, 14 women) were equally divided into the control group (M = 42.06; SD = 12.29) and the experimental group (M = 41.7; SD = 11.46). The two groups were matched for age and gender. The number of participants was calculated with G*Power software (Faul, Erdfelder, Lang & Buchner, 2007): for an effect size of .25, a significance level of .05 and a power of .80, G*Power indicates a total of 34 participants.

Members of the control group were recruited at random through communication with the general public, or were known to the experimenters. In order to ensure that people with HIP were not recruited into this group, each person was asked to fill in a questionnaire and indicate whether they had already been assessed as with HIP, or whether they thought they might have HIP. The majority of the experimental group were members of MENSA France. MENSA is an international association that is open to people who score in the top 2% of the general population on an intelligence test (equivalent to a TIQ above 130). One participant was recruited via Cogito'Z and two were recruited via psychologists. All members of this group, therefore, had a TIQ equal to, or higher than 130. In terms of geographical location, they were spread throughout France.

Members of both groups had normal or corrected-to-normal vision and were French speaking. Exclusion criteria were a diagnosis of dyslexia, dysorthographia or attention deficit disorder. All signed a written consent form.

Materials

The lexical decision task was based upon a list of 120 words drawn from Bonin et al. (2015) which, among other things, evaluated the sensory experience associated with French words. This initial list was then divided into two categories: strong sensory words and weak sensory words. To categorise words, we applied the quartile method to the scores reported in Bonin et al. (2015), which ranged from 1.09 to 6.13 (on a 1–7 Likert scale). The first quartile grouped scores ranging from 1.09 to 2.35, and the fourth quartile grouped those ranging from 4.87 to 6.13. Our strong sensory words corresponded to the 60 words that scored most highly (from 5 to 6.13) and weak sensory words corresponded to those that scored lowest (from 1.24 to 1.97). The lexical frequency of words was checked using freqfilms2 provided by Lexique.org. (New et al., 2004): strong sensory words (M = 103.84, SD = 161.70), weak sensory words (M = 92.06, SD = 167.52) ($t\,(120) = .40, p =.69, d = .07$).

We then created two lists of words for each of the two categories: a list of 30 words and a list of 30 non-words. Non-words were generated by modifying a single letter of the initial word (e.g., gâteau [cake] ⇒gâpeau; citron [lemon] ⇒cifron; druide [druid] ⇒draide; lorsque [when] ⇒lursque). This resulted in four sets of items: strong sensory words (SSW), strong non-sensory words (SNSW), weak sensory words (wSW) and weak non-sensory words (wNSW). Finally, a second, different set of words and non-words were used in the familiarisation phase. This set consisted of words with intermediate sensory scores (ranging from 3.24 to 3.27, Quartile 2 in Bonin et al., 2015). Table 1 shows the number of letters for each category of words and phase of the experiment.

Phase	SSW	SNSW	wSW	wNSW	Number of words
Familiarisation	4.88	4.88	4.88	4.88	8
Experimental	5.17	5	5	4.93	120

Table 1. Number of letters in each category of words and phase of the experiment.

Procedure

Given the geographical distribution of the experimental population, the experiment was run in participants' homes using OpenSesame software (Mathôt, Schreij & Theeuwes, 2012). Due to the experimental setup, and to avoid the participant becoming aware of the tested variables and the aim of the task, we ensured that each software component was given an obscure name. Participants were asked to carry out the experiment in the best possible conditions, at a time when they could give the task their full attention. The same instruction was given to the n-HIP group.

The experiment was divided into two phases, familiarisation and experimental. In both cases, the lexical decision-making paradigm was used (Meyer & Schvaneveldt, 1971). The total duration of the experiment was five minutes.

Familiarisation phase

Familiarisation began with the presentation of the task and instructions. Participants were told that either words or non-words would be presented, and that they should indicate as quickly as possible whether they were real French words or not.

First, a fixation point appeared in the centre of the screen for 300 ms. This was followed by a word or a non-word that appeared in the same place. The word remained on the screen until the participant pressed a button corresponding to 'yes' (a word) or 'no' (a non-word). Both words and non-words were presented in 36 Mono black on a white background. The order of presentation of words and non-words was randomised for each participant, and response keys were balanced between participants. They were asked to respond using their left index finger for the left key (yes or no answer) and their right index finger for the key on the right (yes or no answer). The familiarisation phase consisted of eight items.

Experimental phase

The experimental phase used the same design as the familiarisation phase. It consisted of 120 items.

Results

Statistical analyses were carried out using JASP software (Wagenmakers et al., 2018a, 2018b). First, we calculated the mean error rate for words for the HIP group (1.03%) and the n-HIP group (1.68%). The difference was non-significant (F (1, 32) = .617, ns). The mean error rate for non-words was .98% for the HIP group and 2.84% for the n-HIP group. This difference was significant (F (1, 32) = 6,017, p < .05, η^2 = .158), and indicated that the n-HIP group made more errors when rejecting non-words than the HIP group (n-HIP = 3.41; HIP = 1.47). We also calculated mean correct response time for words and non-words for both groups. Statistical analyses were run on smoothed results using the substitution method beyond two standard deviations, with a maximum tolerated substitution of 10%. We first present results for words, and then non-words.

Words

In this condition, the participant was expected to answer 'yes' (i.e., it is a word in the French language). A two-factor ANOVA was conducted with sensoriality as the within-subjects factor, and group as the between-subjects factor. A main factor analysis found a significant effect of sensoriality (F (1, 32) = 52.95, p< .001, η^2 = .568): strong sensory words were processed faster than weak sensory words (SSW = 633.87; wSW = 701.03). The analysis also identified a significant main effect of group (F (1, 32) = 16.74, p < .001, η^2 = .34): HIP participants responded more quickly than n-HIP participants (HIP = 605.95; n-HIP = 728.95).

The interaction between the two main factors was significant (F (1, 32) = 8.219, p = .007, η^2 = .09). Planned comparisons showed: a) with respect to sensoriality, strong sensory words were processed faster than weak sensory words in both the HIP group (wSW = 626.302; SSW = 585.60), (t (16) = 4.41, p< .001, η^2 =.54), and the n-HIP group (wSW= 775.76; SSW = 682.13), (t (16) = 5.85, p < .001, η^2 =.68); with respect to groups, the HIP group processed both strong sensory words (t (32) =3.04, p = .005, η^2 = .22) and weak sensory words (t (32) = 4.80, p < .001, η^2 = .41) faster than the n-HIP group.

These results partially validate our hypothesis: the HIP group responded more quickly than the n-HIP group, especially for weak sensory words. We present mean correct answer response times for words in Table 1, and illustrate our findings in Figure 1.

	Sensoriality				
	wSW		SSW		
Participants	M	SD	M	SD	Significance
n-HIP	775.76	103.41	682.13	108.10	***
HIP	626.302	76.01	585.60	73.88	***

*Table 1. Mean lexical decision time in milliseconds and degree of significance between mean lexical decision time for weak sensory words (wSW) and strong sensory words (SSW). *** p<.001.*

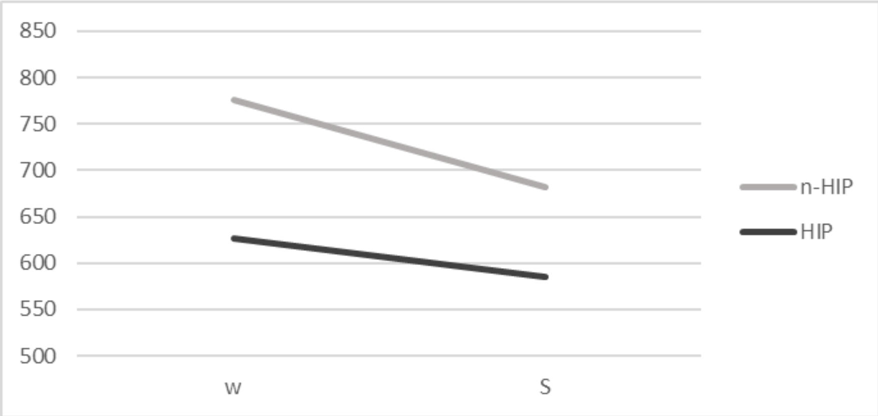

Figure 1: Mean lexical decision time (in milliseconds) for words as a function of group (n-HIP vs. HIP) and sensoriality: weak vs. strong (w, S).

Non-words

In this condition, participants were expected to answer 'no' (i.e., the word is not in the French language). We performed a two-factor ANOVA with sensoriality as a within-subjects factor, and group as a between-subjects factor. No interaction was observed between the two factors (F (1, 32) = 1.911; ns) and there was no main effect of sensoriality (F (1, 32) = .215; ns). On the other hand, a main effect of group was observed (p = .011). HIP participants rejected a non-word faster than n-HIP participants (HIP = 704.88; n-HIP = 903.05).

Ratio strong minus weak sensory words

In addition, we also calculated the difference between response times for strong and weak sensory words, for both groups. The ANOVA highlighted a significant difference (F (1, 32) = 8.22, p <.01, η^2 = .204), which indicated that weak sensory words had more influence on HIP participants (-40.70) compared to n-HIP (-93.63). Finally, the mean difference between strong and weak sensory words (M DIFF = −40.70) in the HIP group was significantly smaller than in the n-HIP group (M DIFF = −93.63). This result demonstrates a greater sensitivity to sensoriality in HPI.

Discussion

It now seems to be agreed that HIP individuals should not only be characterised by their intellectual skills. If we consider that creativity should be taken into account, the clinical observations of Siaud-Facchin (2008) and Revol (2015) suggest that we should pay attention to the higher sensory sensitivity in HIP individuals compared to non-HIP persons. The aim of this work was to test this observation experimentally.

We therefore used a lexical decision task based on strong and weak sensory words drawn from Bonin et al. (2015). As expected, our results indicate that lexical decision times are shorter for strong sensory words than weak sensory words, which is in line with the literature (Juhasz et al., 2011; Juhasz & Yap, 2013; Bonin et al., 2015). However, while our hypothesis focused primarily on strong sensory words, our results regarding weak sensory words provide the strongest evidence of sensorial sensitivity in HIP people, notably their sensory hypersensitivity.

Our findings suggest that: 1) the person with HIP processes sensory information very differently, depending on whether it is weak or strong; and 2) he or she has greater sensitivity to weak sensory items than the typical, n-HIP individual. Hypersensitivity to sensory information in HIP individuals manifests as a significant reduction in the mean difference in processing time between weak and strong sensory stimuli, compared to n-HIP individuals.

This indicates that the HIP person has heightened sensory perception, especially when the stimulus is weak. Therefore, our results support the hypothesis that people with HIP perceive and process sensory information, both weak and strong, faster than non-HIP people.

With reference to Friston's predictive coding theory (Friston, 2005; Friston, Kilner & Harrison, 2006; Friston & Stephan, 2007; Friston, 2009; Friston, 2010) our results shed light on the cognitive functioning of people with HIP. Friston's theory states that adaptation to the environment is an essential function of our brain, which processes information through hierarchical generative models (HGM). The function of the latter is to deduce the cause of sensory signals.

At the moment of perception, both sensory inputs and the probable causes of these inputs are processed. The underlying aim of HGMs is to minimise prediction error, thus optimising individual adaptation. Perceptual content (Seth, 2014) is the result of predictive signals generated by HGM based on what is instantiated as a probable cause of perceived sensory signals. Depending on the size of the prediction error resulting from the fit or misfit between predictive signals, and signals from the 'real' world, new predictive signals are developed through updates from the HGMs.

The question is, therefore, whether the heightened sensory sensitivity of HIP individuals serves to limit prediction errors because updating the internal model is difficult, or because the perception of prediction errors is suboptimal, due to an insufficiently stable internal model.

Finally, the main limitation of our study is that the studied phenomenon does not fully qualify as hyperesthesia, as described by Siaud-Facchin (2008). Although we were able to confirm overall 'heightened sensory capacity' in individuals with HIP, we were unable to verify whether all of the five skills listed by Siaud-Facchin (visual, auditory, gustatory, olfactory, and kinaesthetic) were affected. While our study demonstrates that the perception of sensoriality in the person with HIP differs from the non-HIP person, it does not tell us anything about the discriminatory capacity of the activated sensory dimension. We have already launched a study to investigate this question.

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