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Cognitive Interactions within Sensory Information in Perception

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July 2022

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Abstract

The dynamics present during early information processing at the sensory level of the auditory system have long been studied, and there are two broad views of this processing. The purely bottom-up view is that sensory information is passed up to higher-level cognitive systems in an automatic process of successive recoding. By contrast, the top-down view is that cognitive processing can interact with sensory processes to modify representations even at the earliest levels of sensation. One way of understanding these interactions is to examine individual differences that are not simply reflective of lower-level sensory systems, especially those under cognitive control such as attention. While findings exist that document a relationship between individual differences in auditory attention and visual working memory (WM; Giuliano et al., 2014), few studies have investigated the relationship between individual differences in auditory attention/WM and early speech processing. The current study was designed to assess the relationship between individual differences in attention/WM and signal detection of speech sounds In addition, the higher-level cognitive attribute of "dissociation"--a feeling of disconnection from the immediate situation--was also measured to approach higher-level differences in attention. We examined how differences in dissociative states relate to attention and signal detection. Participants were presented with a task that served as a measure of auditory working memory (WM) and selective attention, a two-step N-Back (2-Back) task, and a task that served as a measure of participants' ability to detect speech signals embedded in noise. Survey measures for cognitive dissociation were also collected for each participant. Signal detection and WM task performance were correlated with dissociation survey scores. Additionally, WM and selective attention are correlated with speech signal detection, although primarily in terms of false alarm errors.

Introduction

One view of perception is a bottom-up view in which physical signals in the environment are converted to neural signals by sensory systems (eyes, ears, etc.) and then transmitted from the peripheral nervous system to the central nervous system with successively higher perceptual and cognitive representations. By this simple model, low-level sensory and higher-level perceptual processes execute sequentially from lower to higher processing, which explains perception as a purely passive system, in which patterns of stimulus input are transmitted along sensory pathways to higher level cognitive processing (Barlow, 1961). This general structure and flow, segmented and unidirectional, is reflected in the prevailing stance of perception within cognitive psychology, as a bottom-up, passive process.

However, this model may not account for all kinds of perception. Some research suggests that speech perception may depend on active cognitive processing involving top-down interactions with early sensory processing (Heald & Nusbaum, 2014; Reis et al., 2021). This top-down interaction is a crucial difference from the traditional passive system. Other research demonstrates individual differences in cognitive processes, like selective attention (SA; Unsworth & Spillers, 2010) and working memory (WM; Unsworth & Engle, 2007). This suggests speech perception may differ between individuals given the role of cognitive processes in speech understanding. This active model of speech perception provides a different approach for understanding the phenomenon of hearing loss in older adults, as previous research has found evidence that the sensory deficits involved impose a compensatory higher demand on cognitive resources, which impacts memory as limited cognitive resources are also expended on processing signals in addition to committing them to long-term storage (Rabbitt, 1991; Murphy et al., 2000; Wingfield et al., 2005).

Furthermore, this active model of speech perception, introducing individual cognitive differences, engages rather well with studies concerning dissociation (i.e., studies concerning the perception of signals, that are not objectively present in one's environment) wherein cognitive interpretation affects perceptions. These studies suggest that dissociation may be the result of misattribution of auditory verbal imagery coupled with "fantasy proneness" (Merckelbach & van de Ven, 2001; Moseley et al., 2016), and may also reflect specific impairments in one's ability to register self-generated verbal imagery as having been purely internal (Pinheiro et al., 2018). It should be noted that the subjective experience of religiosity has also been viewed under this lens of interaction between cognitive and perceptual processes, in the form of observing the effects of training on the quality of reported religious experiences (Luhrmann et al., 2010, 2013).

However research on dissociation while taking into account individual cognitive differences has not specifically investigated effects on early sensory processes (e.g., signal detection). The goal of the current study is to establish, more concretely, whether individual differences in attention and WM might differentially predict signal detection ability within the domain of speech perception. Secondary to this primary aim, given the previous literature on this subject, dissociation/hallucination tendencies were investigated as a possible factor that might more broadly predict individual differences in the relationship between SA/WM and signal detection ability.

Selective Attention & Working Memory

As a caveat, it is important to note that, when it comes to understanding selective attention (SA) and WM as distinct cognitive processes, there have recently been several studies that suggest an extensive overlap between the two (Gazzaley & Nobre, 2012). As much as they may overlap, however, there are certain characteristics of each that are important and helpful in distinguishing them from one another as well as the other, less relevant elements of attention, which is why they will continue to be individually referenced.

SA refers to the process by which an individual selects and focuses on a certain target stimulus for further processing while also ignoring distractors (Stevens & Bavelier, 2012). We start with the assumption that SA is linked to signal detection. Giuliano et al. (2014) found that early auditory evoked potentials (AEPs), which represent the detection of signals, were modulated by auditory SA. Within this study, WM was measured through a visual change detection task (Luck & Vogel, 1997) and examined for its relationship with the attention modulation of AEPs which were measured during a task designed to emphasize early selection in a dichotic listening task (Giuliano et al., 2014). The study found that AEPs resulting from linguistic probes on the dichotic listening task were modulated by attention. This relationship between auditory SA and signal detection was then found to correlate with performance on a separate measure of visual WM (Giuliano et al., 2014). With this evidence of a connection between visual WM, auditory SA, and signal detection, the current study will attempt to extend previous research by examining whether auditory SA is linked with WM in the auditory domain as well.

At its basic level, WM serves as a vehicle by which the filtering process of selective attention can occur, as it represents the limits of an individual's general capacity to manipulate while simultaneously maintaining auditory information in a short-term buffer system for ongoing processing. WM capacity has been closely associated with higher-level outcomes like fluid intelligence and scholastic achievement, though evidence suggests that this link is not due to variance in capacity, but rather individual differences in the ability to control attention (Unsworth & Spillers, 2010; Giuliano et al., 2014). Thus, it is possible that greater ability to focus attention complements larger WM capacity because having a large WM capacity does not matter if it is easily filled with distracting stimuli.

Signal Detection

Early auditory encoding is conditioned by experience (Skoe & Kraus, 2012), meaning that experience shapes the basic neural patterns extracted from acoustic signals (Heald & Nusbaum, 2014). Research has demonstrated measurable effects of training on auditory processing (Song et al., 2008; Reis et al., 2021), which is consistent with speech perception being an active process wherein attention and experience influence the earliest levels of sensory encoding in speech (Heald & Nusbaum, 2014). As an active process, the key factor acting as a basis for the current study is this top-down (cognitive to sensory) feedback component that is lacking in passive processes. Sensory processing being altered by feedback from higher cortical levels suggests a possible connection between signal detection of speech and cognitive processes like SA and WM.

Dissociation

Beyond the basic cognitive mechanisms of attention and working memory, there are higher-level cognitive states that are related to perceptual interpretation and understanding of sensory information. For example, dissociative experiences--the feeling of being disconnected from the sensory world--represent an affective state that has been related to a number of memory distortions (see Gallo, 2010. In the present study, we asked whether this kind of high-level cognitive state of dissociation which has been shown to produce memory illusions (Gallo, 2010), may also operate to affect perception directly. Such experiences likely interact with attention (perhaps directing attention to specific pattern properties) and working memory (prioritizing what information is maintained in WM).

Dissociative experiences are not limited to pathological populations (Schurle et al, 2007); a healthy individual might mistakenly hear their name being called or their notification ring on their phone in the absence of such signals. However, previous literature suggests that dissociative experiences may interfere with sensory processing and represent a failure in the ability to integrate information at higher levels of processing which can cause the misinterpretation of sensory inputs (Woody & Bowers, 1994; Brunet et al., 2001; Ozdemir et al., 2015). This cognitive-sensory relationship in question has been previously explored in auditory hallucinations and religious experiences.

Regarding auditory hallucinations, there is some evidence to support the idea that these phenomena are a result of impaired signal detection ability, lending to factors that result in a higher rate of false alarms. For instance, an electroencephalography (EEG) study conducted by Pinheiro et al. (2018) found that participants with a higher predisposition toward hallucination displayed altered processing of self-generated voices, as observed from measurements of their N1 and P2 components. Auditory N1 is considered within event-related potential studies as a putative measure of sensory prediction, one that is generally suppressed in response to self-generated vs. externally generated voices; larger N1 responses may signal increased attention to unexpected sensory events, leading to prediction error (Pinheiro et al., 2018). While P2 is less consistent in its connection with the prediction and comparison of auditory feedback to a self-generated voice, its suppression may represent a more conscious distinction between self-/externally- generated sensory events (Knolle et al., 2013). What Pinheiro et al. found was that N1 responses tended to be increased and P2 responses tended to be unaffected in subjects with a higher predisposition towards hallucination. Pre-stimulus alpha activity, suggested to play a role in modulating N1, was also increased in these subjects, which may imply an impairment in the prediction of error and in the process of registering a self-generated motor command, thereby incorrectly marking internally generated processes as external signals (Pinheiro et al., 2018).

Another reason for considering dissociation alongside attention and signal detection is that there is evidence to suggest that it also can benefit from training effects, under certain circumstances. Luhrmann et al. (2010) conducted a semi-empirical ethnographic study that looked into the experiences of prayer among religious individuals from an experiential evangelical church. What they found was that the subjects' paradigm of highly successful prayer, leading to instances of perceived direct communication with God, closely aligned with indicators of absorption from the Tellegen Absorption Scale.

Additionally, these accounts of prayer quality were describrd in terms of a mix of experience or practice and characteristic proclivity, implying a training effect that is supported by the type of prayer promoted in experiential evangelical churches, which involves the heavy use of and immersion within an individual's mental imagery (Luhrmann et al. 2010). A further investigation by Luhrmann et al. (2013) yielded evidence in support of this effect of prayer on the vividness of mental imagery, and also found a related effect on participants' perceptual accuracy. Participants who had been assigned to the prayer group reported an increased number of unusual sensory experiences, which implies a connection between certain trainable cognitive processes and a tendency toward dissociation. The authors postulate that this process of prayer improves the degree to which participants can focus their attention on mental imagery (Luhrmann et al., 2013). As a brief side note, among individuals who are prone to dissociative experiences and hallucinations, it has been found that auditory verbal imagery has been linked with lower response bias between self-generated and external signals (Moseley et al., 2015), which might suggest that practicing in improving the vividness of mental imagery might exacerbate the number of false signals in even non-clinical individuals with higher absorption tendencies. The reported effects accompanying this increased vividness of mental imagery reinforce the idea that attention is linked to signal detection and the increased occurrence of unusual sensory experiences seems to further imply a link between attention and dissociation.

Since there is a connection between dissociation and attention, as well as with sensory processing, this current study also aims to explore whether dissociative experiences might affect performance on a signal detection task. For the purpose of this goal, a variety of dissociative surveys are used as a general measure of subjects' tendency towards dissociative experiences.

Current Study

The present study was designed to investigate the relationship between individual differences in auditory WM and auditory SA with individuals' ability to detect patterns of speech signals (vowel sounds) embedded within noise. This task may be related to the experience of auditory hallucinations (see Luhrmann et al, 2013) and may predict which people have the "propensity" to develop increased auditory hallucinations through practice (as suggested by Luhrmann et al. 2010). In order to assess these differences, participants performed two tasks. A 2-step N-Back task (2-Back) was used as a standard measure of WM and SA (Kirchner, 1958). A target detection in noise task (SNDT) measured the ability to detect signal embedded in noise.

In addition to the overarching hypothesis, there is one more specific hypothesis of the current study. Namely, participants who report greater prevalence and frequency of dissociative experiences on dissociation surveys might be predicted to perform worse on the tasks measuring attention and signal detection. This is predicted because dissociative tendencies can be viewed as interfering with necessary attention control required on the 2-Back WM task as well as providing a predisposition towards false alarms on the SNDT.

Methods

All experimental procedures were approved by the Institutional Review Board at the University of Chicago. Recruitment and data collection took place during the months of April and May of 2022. In the interest of replicability, all data will be shared on open science frameworks after it has been thoroughly de-identified.

Participants

Participants (*N* = 40) consisted of students (ages 18 and older) from the University of Chicago and individuals recruited through Prolific (www.prolific.co) [28 April – 6 May 2022], an online survey distribution platform. Recruitment of students was primarily done through the university's Sona Systems portal. Student participants were offered one credit per hour of participation, in the case that they were concurrently enrolled in a course that requires its students to obtain research credits. Otherwise, volunteers were not materially compensated. The subjects that were recruited through Prolific were compensated with $7.00 per 40 minutes spent on the experiment. Before participation in the study, participants were required to give their informed consent.

Materials

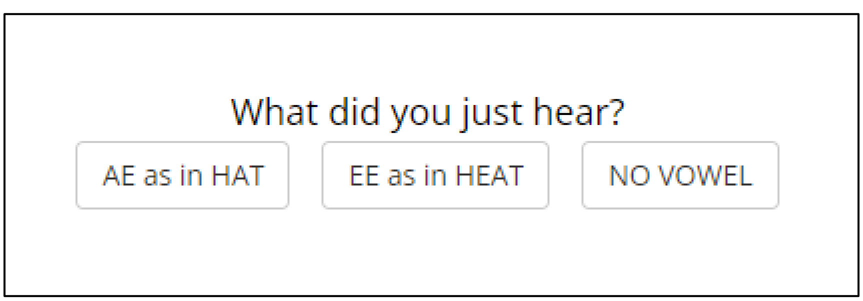
Surveys: Qualtrics was used to create and distribute the surveys, which, apart from general demographic questions, included several surveys that address participants' frequency of dissociative experiences. The Dissociative Experiences Scale-II (DES-II) measures a wide variety of types of dissociative experiences, from daydreaming to dissociative identity disorder (Carlson & Putnam, 1993). The Tellegen Absorption Scale (TAS) measures participants' tendency to lose themselves in thoughts, feelings, or sensations (e.g., "When I listen to music, I get so caught up in it that I don't notice anything else.") (Tellegen & Atkinson, 1974). Lastly, the Launay-Slade Hallucination Scale (LSHS-R) was used to measure the predisposition towards hallucinations in healthy individuals (Bentall & Slade, 1985).

Tasks: The experiment contained a task that served as measures of auditory WM and attention, the 2-Back. A second task acted as a measure of signal detection ability, the SNDT. The vowel stimuli for each of these tasks were created using Praat (Boersma & Weenink, 2022). All stimuli were RMS normalized to -25 dB relative to full scale (where 0 dB represents audio clipping). Within the lab, the volume for the computers was set so that all sounds fell into a range of 60-75 dB as measured by a sound level meter, and all tasks for participants within the lab were presented through headphones.

On the 2-Back, participants were asked to listen to a random sequence of spoken letters on the computer and told to press the spacebar every time the letter that they hear matches the letter that was presented two positions previously. For example, in the sequence of letters: "E, G, G, E, G, P, P, P" the letters in red would be the ones for which the participant would press the spacebar. Letter stimuli were taken from the English alphabet and were presented to participants by a digital female voice. The task was separated into four 90-second presentation blocks for a total of 6 minutes of expected duration for the participant to complete. Each block contained 10 target and 20 non-target stimuli for a total of 120 stimuli presented in total.

The SNDT plays a sound sample containing a recorded vowel sound embedded in white noise. Participants were instructed to determine whether they heard EE as in "heat" or AE as in "hat" or no vowel at all inside the noise-- they had three alternative responses on each trial (see Figure 1). The task contains variations in the ratio of vowel amplitude to noise amplitude in each stimulus sample to measure each participant's ability to detect speech patterns in noise. Participants were given 90 trials which took about 10 minutes to complete (cf. Van Hedger, 2021).

Figure 1. Signal Noise Detection Task Example



Procedure

Some participants were tested in the lab in person and others were tested remotely. For the participants that were tested in the lab, participants and researchers were both required to be in compliance with health and safety regulations in order to proceed, due to the circumstances of the study occurring during a pandemic. After written consent was obtained from the participant, they were assigned to one of three desktop computers, separated from one another by sound-shielded dividers, and listened to stimuli over headphones with sound samples calibrated to 65 dB SPL. Participants were first instructed to complete the 2-Back WM task. Upon completion of this first task, the participants were instructed to begin the SNDT. After both tasks were completed, the participant then completed the surveys. After the tasks and the surveys were finished, the participant was fully debriefed.

Remote subjects signed up for the study on Prolific and were given instructions to pay close attention to the auditory stimuli presented in the tasks. There was one attention check placed in each of the surveys (3 total), and each was crafted in the style of the survey in which they were embedded, containing messages to select certain choices. Attention checks were used as a way to promote engagement with the surveys and subjects that failed those checks were screened out.

Analysis

For both the WM task and the signal task, performance was scored as hits, misses, false alarms, and correct rejections. Regarding the 2-Back, hits were coded when the participant correctly responded to a letter that had been repeated; misses were recorded when participants failed to press the spacebar to a repeated letter; false alarms were coded when the participant responded to a non-repeated letter; correct rejections were simply recorded when participants did not respond to non-target stimuli. Regarding the SNDT, hits were coded when participants correctly identified the vowel in trials where there was a vowel present within the noise, misses were scored when the stimulus was incorrectly classified as having no vowel and when the wrong vowel was selected; false alarms on the SDNT were coded when the participant indicated presence of a vowel in the noise when no such vowel was present; correct rejections were coded as instances in which no vowel was present and the subject appropriately responded as such.

Correlation matrices were used to provide summaries of the relationships within the data. Following that, multiple linear regression was used to investigate these relationships between performance on the 2-Back, performance on the SDNT, and subjects' scores on the dissociative surveys. To the extent that detecting vowels in noise depends on attention and working memory we would predict performance on the 2-Back should positively correlate with performance on the SDNT. To the extent that a propensity to have dissociative experiences affects perception scores on the dissociative scales should negatively correlate with performance on the other two tasks, and false alarms (trials where subjects registered the presence of a target in its absence) on both tasks should positively correlate with scores on the dissociative scales. Performance, more specifically and with regard to the task coding, refers to hits and correct rejections as positive indicators and false-positives/misses as negative indicators.

Results

A two-tailed correlation analysis was carried out using the positive and negative performance indicators combined into 'correct' and 'incorrect' variables for each of the tasks, against the dissociation surveys used in this study (see Table 1). None of the first order correlations between WM performance and detection performance and the surveys were significant. The surveys of dissociative experience do show some significant relationships at least between the Tellegen and the DES. The lack of significant correlation with the Launay-Slade suggests that the responses on dissociative experiences in these participants were not due to a propensity for hallucinations. Negative performance on both the SNDT ($r(38) = .26$, $p = .113$) and the 2-Back ($r(38) = .28$, $p = .083$) exhibited a small positive but non-significant correlation trend with scores on the hallucination scale as measure by LSHS. The correlation between positive performance on the SNDT ($r(38) = .15$, $p = .366$) and dissociation scores on the LSHS shows slight positive correlation, though far from significant. In general, these results trend in the direction that subjects who performed poorly on the tasks, tended to also score more highly on the LSHS.

Table 1. Performance vs. Dissociation

	TAS	DES-II	LSHS	sndt_correct	sndt_incorrect
TAS	—				
DES-II	0.340 *	—			
LSHS	0.182	0.464 **	—		
sndt_correct	0.010	-0.107	0.147	—	
sndt_incorrect	-0.218	0.138	0.255	-0.118	—
2back_correct	0.058	-0.153	-0.279	0.038	-0.301
2back_incorrect	-0.065	0.148	0.277	-0.037	0.308

Note. * p < .05, ** p < .01, *** p < .001; *N* = 40; H_a is a two-tailed correlation

Additionally, a small correlation between 2-Back performance and doing poorly on the SNDT was found on negative ('incorrect'; *r*(38) = .31, *p* = .053) indicators of performance. Conversely, little to no relationship was found between these positive (*r*(38) = .04, *p* = .817) and negative (*r*(38) = -.04, *p* = .823) indicators of 2-Back performance and the number of correct responses given on the SNDT. These findings suggest that the number of trials to which subjects incorrectly responded was correlated with their performance on the 2-Back. Further analyses were split between the positive and the negative indicators and involved in a further one-tailed test, including the more specific scores of performance since they generally shared the same direction of correlation.

Positive Performance (Table 2):

Further inspection of the relationships observed in Table 1 yielded significance. Correct rejections on the SNDT were found to share a linear relationship with dissociation scores on the DES-II, represented by a negative Pearson correlation coefficient, *r*(38) = -.37, *p* = .01. An interpretation of this finding would be that participants who score highly on the DES-II are more likely to make fewer correct rejections in signal detection (knowing when a target stimulus is not present).

Table 2. Positive Performance vs. Dissociation

		DES-II	LSHS
DES-II	Pearson's r	—	
	p-value	—	
LSHS	Pearson's r	0.464	—
	p-value	0.999	—
tot_sndt_HIT	Pearson's r	0.084	0.224
	p-value	0.698	0.918
tot_sndt_CR	Pearson's r	−0.367 **	−0.169
	p-value	0.010	0.149
2back_HIT	Pearson's r	−0.276 *	−0.290 *
	p-value	0.042	0.035
2back_CR	Pearson's r	−0.025	−0.164
	p-value	0.439	0.157

Note. H_a is negative correlation
Note. * p < .05, ** p < .01, *** p < .001, one-tailed

Hits on the 2-Back were also found to be significantly and negatively correlated with scores on both the DES-II (*r*(38) = -.28, *p* = .042) and the LSHS (*r*(38) = -.29, *p*=.035). Subjects who respond appropriately when the target stimulus is presented were more likely to report lower levels of dissociation on the DES-II and the LSHS, which may be indicative of better reality-testing among these individuals.

Multiple regression analysis was used to determine the extent to which correct rejections on the SNDT and hits on the 2-Back could be used to predict dissociation scores on the DES-II. These two predictors were found to significantly explain the variance in DES-II scores, $R^2 = .19$, $F(2, 37) = 4.2$, $p = .023$. Individual analysis of predictors showed that correct rejections were a significant predictor of DES-II score, $\beta = -.33$, $t(39) = -2.22$, $p=.033$. On average, an increase of DES-II score by 1 point resulted in a -0.46 decrease in the number of correct rejections that a subject will make, B = -.464, 95% CI[-.89, -.04]. Hits on the 2-Back were not shown to be a significant predictor of DES-II scores, $\beta = -.23$, $t(39) = -1.51$, $p = .139$.

Negative Performance (Table 3):

Among the specific negative indicators of performance, the number of 2-Back misses was found to share a small positive significant correlation with dissociation scores from both the DES-II ($r(38) = .28$, $p = .042$) and the LSHS ($r(38) = .29$, $p = .035$). Such findings suggest that subjects who scored higher on the dissociative surveys were also more likely to miss the presentation of the target symbol on the 2-Back task.

Table 3. Negative Performance vs. Dissociation

		DES-II	LSHS
DES-II	Pearson's r	—	
	p-value	—	
LSHS	Pearson's r	0.464 **	—
	p-value	0.001	—
tot_sndt_FP	Pearson's r	0.352 *	0.250
	p-value	0.013	0.060
tot_sndt_MISS	Pearson's r	−0.069	0.087
	p-value	0.663	0.297
2back_FP	Pearson's r	0.021	0.162
	p-value	0.449	0.159
2back_MISS	Pearson's r	0.276 *	0.290 *
	p-value	0.042	0.035

Note. H_a is positive correlation

Note. * p < .05, ** p < .01, *** p < .001, one-tailed

The number of false positives that subjects made on the SNDT was found to share a significant and moderate correlation to DES-II scores, $r(38) = .35$, $p = .013$. This result suggests that subjects with a larger number of false positives on the SNDT may also tend to have higher dissociation scores on the DES-II. While it was not significant, the linear relationship between LSHS scores and the number of false positives on the SNDT still showed a small positive correlation, $r(38) = .25$, $p = .06$.

Multiple regression analysis was then conducted to investigate whether or not DES-II scores could be predicted by 2-Back misses and SNDT false positives. Collectively, the model was found to explain a statistically significant amount of variance in DES-II scores, $R^2 = 0.1714$, $F(2,37) = 3.83$, $p = .031$. As a standalone predictor, SNDT false positives were shown to predict DES-II scores to a significant degree, $\beta = .31$, $t(39)=2.06$, $p = .047$.

Simple linear regression was conducted to determine the extent to which misses on the 2-Back could be said to predict subjects' scores on the LSHS. The results indicated that 2-Back misses just skirted significance but trended toward a relationship consistent with the previous analysis, $\beta = -.29$, $t(39) = -1.87$, $p = .07$.

In terms of significant correlations, scores on the DES-II were found to be negatively correlated with SNDT performance, showing a direct relationship with false positives. A similar result was obtained when looking at the relationship between 2-Back performance and DES-II scores, 2-Back misses were positively correlated to SNDT scores. LSHS scores were, however, only significantly correlated with 2-Back performance. The results of regression analyses showed that DES-II scores could be predicted to a significant degree using a model containing SNDT false positives.

Working Memory and Signal Detection:

According to the first correlation matrix (Table 1), there is a nonsignificant, moderate correlation between poor performance on the SDNT and general performance on the 2-Back task. The specific performance indicators for the 2-Back, both positive and negative, were entered into a correlation matrix in order to narrow down the specific relationships to investigate. Looking at the relationships between poor performance on the SDNT and false positives on the 2-Back, the results of the Pearson correlation suggest a positive association between false positives on the 2-Back and the number of incorrect responses on the SNDT, $r(38) = .33$, $p = .036$. These data suggest that subjects who experienced fewer false positives and correctly rejects trials with no target stimulus in them tended to not do as poorly on the SNDT. Narrowing the data further, a correlation matrix was made to identify which negative performance indicator of the SNDT was correlated with the false positive rate in the 2-Back. The linear relationship between the number of misses a subject got on the SNDT and the number of false positives they got on the 2-Back was shown to have a small, but nonsignificant Pearson coefficient, $r(38) = .21$, $p=.2$.

Simple linear regression was conducted using the variable for total incorrect responses on the SNDT and having the predictor be the 2-Back false positive score. The model explained a statistically significant amount of variance in poor SNDT performance, as predicted by 2-Back false positives, $\beta = .33$, $t(39) = 2.18$, $p = .036$.

Discussion

Analyses revealed significant associations between metrics for signal detection ability and psychometric scales for dissociation. The hypothesized relationship between performance on both tasks and DES-II scores was supported by the data, yielding a negative correlation to a significant degree as expected, however, SNDT performance did not correlate negatively with scores on the LSHS, even showing a minimal positive correlation, while 2-Back false positive response rates did. These results suggest that subjects who tended to have a higher predisposition towards dissociative experiences also tended to perform poorly on tasks measuring SA/WM and signal detection.

Secondly, auditory SA/WM performance, primarily represented by scores on the 2-Back, was found to be a significant predictor of performance on the SDNT, which was used as a measure of speech signal detection ability. From Table 2, the relationship between SNDT correct rejection and 2-Back hits suggests that holding information in working memory may be part of the process of ignoring irrelevant noise while listening for a target. As Awh et al. (2006) point out, selective attention to stimuli in the external environment is related to the process of selecting information in WM. Correct rejections (saying there is no speech in the noise) may be potentiated by holding in mind an auditory image of the two possible targets. This mental maintenance of representations within short-term memory may be the basis for holding the target in mind in the 2-Back task. By contrast, increased alarms may be related to dissociation in that listeners imagine hearing something they are listening for which is not truly present when the stimulus situation is somewhat ambiguous due to noise. This finding would support the primary hypothesis that individual differences in attention/WM are related to signal detection in early sensory processing.

With regard to the potential future directions of this research, it would be interesting, after replication has corroborated the findings of this study, to further explore this relationship between dissociation and perception in terms of what dissociation means with respect to underlying cognitive mechanisms and real-world perception. The relationship in other research (REFs) between dissociation and hallucination suggests that there may be an underlying relationship between these that affects perception rather than just the expectation or the belief that something will be or has been perceived. Research using the "white Christmas task" has suggested that reporting perceptual experiences may be related to dissociative experience but connecting this to cognitive mechanisms will take further research.

In conclusion, individual differences in attention and working memory were found are related to false alarm errors in speech signal detection. Further attention and working memory also significantly predict dissociation scores. As such, this relationship between a cognitive process like SA/WM and a sensory process like signal detection especially in relationship to dissociation suggests the importance of higher-level cognition in the early encoding of speech signals

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