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Effect of working memory load on tactile n-back task

Efeito da carga de memória operacional na tarefa n-back tátil

Efecto de la carga de memoria de trabajo en la tarea táctil n-back

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ABSTRACT

The present study investigated the characteristics of tactile working memory using the N-Back Task. The participants (n = 16), all sighted, performed the task with working memory loads equivalent to maintaining one, two, or three letters in the working memory (N-Back 1, N-Back 2, and N-Back 3). The frequency of commission and omission errors was analyzed as a function of memory load. The results indicate an increase in the frequency of omission errors due to this factor. The working memory load did not significantly influence commission errors. In general, our results suggest that the tactile N-Back task may represent a promising method for the assessment of working memory in blind and sighted participants.

KEYWORDS:

Tactile memory; Working memory; N-Back task.

RESUMO

O presente estudo investigou as características da memória de trabalho tátil por meio da Tarefa N-Back. Os participantes (n = 16), todos videntes, executaram a tarefa com cargas mnemônicas equivalentes a manutenção de uma, dois ou três letras na memória de trabalho (N-Back 1, N-Back 2 e N-Back 3). Foram analisadas a frequência de erros de comissão e a omissão em função da carga mnemônica. Os resultados apontam um aumento na frequência dos erros de omissão em função desse fator. As comissões não foram influenciadas significativamente pela carga da memória de trabalho. Em linhas gerais, nossos resultados sugerem que a tarefa N-Back tátil pode representar um método promissor para a avaliação da memória de trabalho em participantes videntes e não videntes.

PALAVRAS-CHAVE:

Memória tátil; Memória operacional; Tarefa N-Back.

RESUMEN

El presente estudio investigó las características de la memoria táctil de trabajo utilizando la Tarea N-Back. Los participantes (n = 16), todos videntes, realizaron la tarea con cargas equivalentes a una, dos o tres letras en la memoria de trabajo (N-Back 1, N-Back 2 y N-Back 3). Los errores de comisión y omisión se analizó de acuerdo con la carga de trabajo. Los resultados indican un aumento en la frecuencia de errores de omisión debido a este factor. Las comisiones no fueron influenciadas significativamente por la carga de memoria de trabajo. En general, nuestros resultados sugieren que la tarea N-Back táctil puede representar un método prometedor para la evaluación de la memoria de trabajo en participantes videntes y no videntes.

PALABRAS CLAVE:

Memoria táctil; Memoria de trabajo; Tarea N-Back.

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How does vision relate to touch? This question posed by John Locke in the late seventeenth century (Degenaar & Lokhorst, 2017) is still a current and controversial issue. Clinical case studies show that blind people who have grown up who have spent much of their lives using touch as a substitute for vision have great difficulty adapting when they can see. Surgical interventions have given or returned sight to many. Studies of these cases show that most of the time these people cannot visually recognize the objects they have recognized by touch (Sacks, 1993), and suggests a dissociation between the processing of visual and tactile information[6]. The sensory information acquired from vision and touch is codified in different sensory systems

[6] Objects can be perceived in an active (haptic) or passive (tactile) way (Fernandes & Albuquerque, 2012; Gallace & Spence, 2009;

and processing in different cortical areas. However, studies with normal sight people show that, despite the dissociation between these sensory systems, the processing of perceptual tactile information activates brain regions associated with the visual perception (Deibert, Kraut, & Kremen, 1999; Masson, Bulthé, Beeck, & Wallraven, 2016; Ricciardi et al., 2006; Snow, Strother, & Humphreys, 2014).

In a recent study using functional magnetic resonance imaging (fMRI), Masson et al. (2016) showed that haptic exploration generates mental images by activating primary areas of the visual cortex, suggesting that mental representation of haptic forms shares resources of the visual mnemonic system. This kind of result emphasizes the supposition that visual short-term memory can store not only information acquired by vision but also information acquired from the verbal and tactile senses (Baddeley, 2012). However, few studies have explored the tactile sense in the working memory system. Bliss and Hämäläinen (2005), for example, evaluated the possible differences in the memory and processing capacity of visual and tactile information in normal sight persons in a N-Back task, one of the most popular measure of working memory (Yaple, Stevens, & Arsalidou, 2019). In the classic N-Back task, a sequence of letters is displayed, and the participant is requested to identify the repetition, or not, of a letter in the visual sequence presented. Bliss and Hämäläinen (2005) investigated the possible relationship between this classic memory task and its tactile version. Their result suggests that both tasks are sensitive to memory load, but the performance is better in the visual task than in the tactile task. Picard and Monnier (2009) suggest parallel developmental curves for the tactile-spatial and visuospatial working memory. The authors interpreted such parallelism in development as possible evidence that the tactile and visual short-term storage processes share common representation systems. The present study aimed to investigate the working memory performance using a tactile N-Back task procedure adapted from Bliss and Hämäläinen (2005) in a Brazilian normal vision sample.

Gibson, 1962; Loomis & Lederman, 1986; Penha, Garcia, Douchkin, & Da Silva, 2014). In most situations, tactile and haptic information occurs simultaneously, allowing the extraction of the general characteristics of objects. The tactile and haptic concepts are important aspects for a more detailed understanding of this perceptual system. In this paper we use the term tactile in its more general meaning that is acquiring information by touch.

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Method

Participants

Sixteen volunteers (seven males) with mean age of 24.9 years (*SD* = 4.9) took part in one experimental session. All participants had normal or corrected to normal vision and were students at a Federal University in Brazil. All participants had previous experience with the visual n-back task (letters). The Ethics Research Committee approved all procedures (CAAE: 49830115.0.0000.5152).

Table 1.

Sequence of letters used in tactile N-Back task

	N-Back - 1	**N-Back - 2**	**N-Back - 3**
Seq. 1	PFBFOLHCHGJRKRXVTVIS	GNFESFRZBJZKLVKYCTIC	NSIONFVLTFPBKCPJYEZJ
Seq. 2	GIGYXCLCTEOZOSJFRHRH	ZXTZYCPSCHENHIRVBRFJ	RPKXRLFGHLJNVIJSBOTS
Seq. 3	VCYIBIJPEOEKSTSXNZHZ	IXNPTJPOZYKZRHCRGEFG	HEXYHSVINSLGBRLOCPFO
Seq. 4	YLXKXOSPCPFJRJNENHBI	HXLTXPBCNBGJIGYREORF	FEKNFTZJYTXSPOXLRIHL
Seq. 5	GSRTXTIBKEFEPZPOJHJV	YCKYOEROIVSIGLFZLPBN	HPECHLRGNLKZTSKFJVBF

Note. The underlined letter indicates the target letters.

Source: Own elaboration.

Material and stimuli

Tactile stimuli were composed of 20 standard plywood supports (Eucatex®), painted in black, with 98 cm in length, 5 cm in width and 0.3 cm in thickness. Yellow plastic letters measuring 3 cm in height, 1.5 cm in width and 0.2 cm in thickness (relief in relation to the wooden base) fixed in the plywood support (Figure 1). The distance between letters was 2 cm. Table 1 shows the letter sequences used in the tactile N-Back tasks.

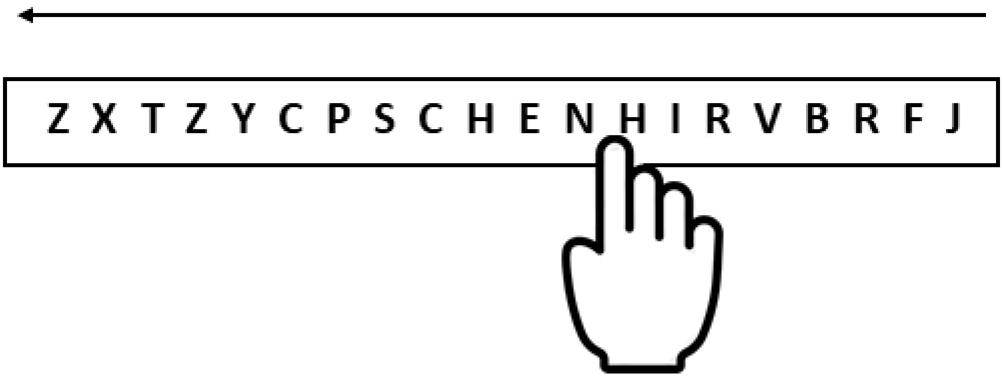
Procedure

The tactile N-Back task required the tactile recognition of letters sequentially arranged. Participants were blindfolded and trained to identify each letter correctly by touch. Training consisted of the tactile recognition of 80 letters placed in four sequences with 20 letters each and had no time limit. The extent of training was defined in a previous pilot study with five participants.

In experimental trials, the participants were required to respond “Yes” when a repeated letter appeared in sequence or “No” when the analyzed letter was new on a sequence and the experimenter moved the support so the participant could explore the letter exactly in front of her/him.

Four conditions were defined: Tactile Recognition, N-Back 1, N-Back 2 and N-Back 3. Each condition presented five sequences consisting of 20 letters. In the condition of tactile recognition, no letters were repeated, and this condition was not characterized as an N-Back task. There were three N-Back conditions (load 1, load 2, and load 3) with four letters repeated in each sequence (target letters).

In N-Back 1 condition, one target letter was repeated after a non-repeated letter. In N-Back 2 and N-Back 3 sequences, the target letter was repeated after two or three non-repeated letters, respectively. Participants received initial instructions on the research procedures as well as relevant ethical explanations. Tasks were carried out on a table with dimensions suitable for their comfortable execution. After signing the Free and Informed Consent Form, volunteers performed the tactile recognition training, with no execution time limit. After training and clarification of possible doubts, experimental tests were initiated. Participants did not receive any feedback on their performance. There was no time limit for analyzing each letter, and after the presentation of 20 letters, the sequence finished and the participant waited for a two-minute interval to start the new sequence. This rest interval between sequences had the purpose of minimizing the interference between sequences. Each condition (Tactile Recognition, N-Back 1, N-Back 2, and N-Back 3) was presented in random order throughout the experimental session. The performance was recorded in a video for a better analysis of data. ANOVA tests were conducted to statistical analysis in frequencies of omission errors (“No” responses to a repeated letter) and commission errors ("Yes" responses to a non-repeated letter) for the N-Back task (N-Back 1, N-Back 2, and N-Back 3).



Source: Own elaboration.

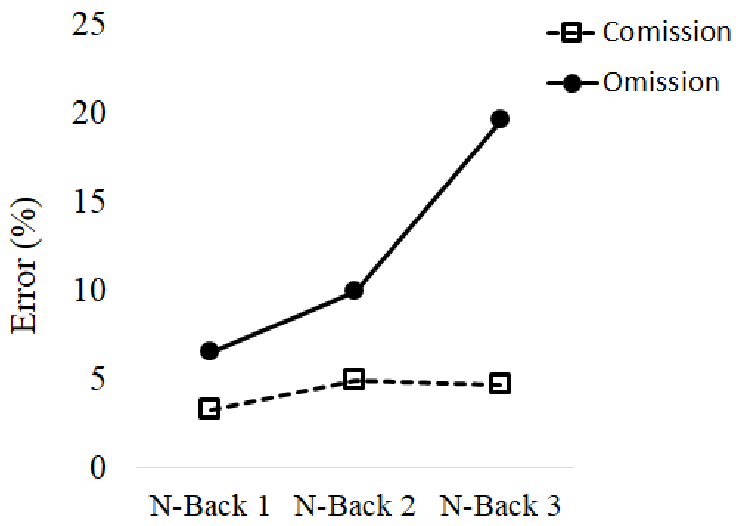
Figure 1.

Schematic representation of stimuli used in the tactile N-Back 2 task.

Results

The tactile recognition condition is not characterized as a N-back task but rather a recognition task, and the data was not included in the n-back statistical analysis. The analysis of the percentage of commission in this condition was 4.75%.

The frequency of omissions in each sequence on N-Back task was divided by four (number of target letters in each sequence), and the frequency of commissions was divided by 16 (number of new letters in each sequence). The analysis of the omission errors was significant as a function of memory load F (2, 30) = 14.491, $p < .001$, $\eta_p^2 = .41$. The post hoc *NK* test ($p < .05$) confirmed a significant difference in the percentage of omission errors between N-Back 3 (19.7%) and N-Back 2 (10%) and N-Back 1 (6.6%) conditions. The same analysis does not show a significant difference between the condition N-Back 2 and N-Back 1. The analysis of the percentage of commission errors did not show a significant increase as a function of memory load, F (2, 30) = 2.487, $p = .10$, N-Back 1 = 3.28%, N-Back 2 = 5%, and N-Back 3 = 4.69%.



Source: Own elaboration.

Figure 2.

Error as a function of memory tactile load (N-Back 1, N-Back 2 and N-Back 3).

General discussion

In general, our results in the tactile N-Back task corroborate previous findings that an increase in the memory load in the N-Back task is associated with an increase in the number of incorrect responses (Bliss & Hämäläinen, 2005). In other words, the greater the number of letters interposed between a letter and its repetition in the sequence, the greater the difficulty of participants in recognizing a repetition. Our results suggest a specific effect of memory load in omission, but not on commission, errors. In n-back tasks, omission errors, not responding to a proper stimulus, are more frequent than commission errors, responding to an inadequate stimulus. According to Meule (2017), these two types of errors may represent different cognitive processes. Our results show that the processes associated with omission errors depend more on working memory resources than commission errors, suggesting that omission errors may be produced by limits in both working memory maintenance and processing.

In agreement with Bliss and Hämäläinen (2005) results, the present study suggests that the tactile N-Back task is a viable tool, as the visual N-Back task, to investigate the working memory system. However, this interpretation is limited since the input condition of the sensory information was not equivalent between modes (Loomis, Klatzky, & Lederman, 1991). This requires future studies that can better establish the similarities and differences between the two systems (visual and tactile) in N-Back task. In a study that addressed this aspect, Picard and Monnier (2009) found evidence that suggests equivalence in the performance of participants in tasks of visual and tactile working memory when the perceptive field is controlled. Finally, this study presented some limitations that will be addressed in future investigations. A limitation was the use of nameable stimuli (letters) that did not preclude the active participation of the phonological memory in temporary maintenance of tactile information. Possible experimental improvements for further studies could be provided by not nameable stimuli (e.g. tactile patterns). In conclusion, the general results suggest that the tactile N-Back task may represent a promising method for assessing working memory in blind and sighted participants.

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