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ARTICLE *in* CURRENT ALZHEIMER RESEARCH · DECEMBER 2014

Impact Factor: 3.8 · DOI: 10.2174/1567205012666141218124744 · Source: PubMed

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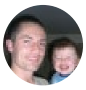

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Expanded temporal binding windows in people with mild cognitive impairment

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SUBMITTED TO: Current Alzheimer Research

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Abstract

Previous studies investigating mild cognitive impairment (MCI) have focused primarily on cognitive, memory, attention, and executive function deficits. There has been relatively little research on the perceptual deficits people with MCI may exhibit. This is surprising given that it has been suggested that sensory and cognitive functions share a common cortical framework [1]. In the following study, we presented the sound-induced flash illusion (SiFi) to a group of participants with mild cognitive impairment (MCI) and healthy controls (HC). The SiFi is an audio-visual illusion whereby two-beeps and one-flash are presented. Participants tend to perceive two flashes when the time-interval between the auditory beeps is small [2; 3]. Participants with MCI perceived significantly more illusions compared to HC over longer auditory time-intervals. This suggests that MCIs integrate more (arguably irrelevant) audiovisual information compared to HCs. By incorporating perceptual tasks into a clinical diagnosis it may be possible to gain a more comprehensive understanding into the disease, as well as provide a more accurate diagnose to those who may have a language impairment.

Introduction

There is a great deal of controversy regarding the predictive validity of standard neuropsychological assessments in identifying early cases of dementia [4; 5] and the underlying causal factors associated with age- and disease-related decrements in cognition [6-9]. Theoretical models of neurological aging have proposed a variety of markers of generalized cognitive decline, including increased intra-individual variability in "intellectual function" [10; 11], reduced processing speed [12], and sensori-motor function decline [13]. It has recently been suggested [14] that research on multisensory integration is warranted as it may facilitate the identification of more sensitive markers of age- and disease-related cognitive decline and also enhance the potential for early intervention and therapeutic applications, for example, focusing on multisensory stimulation [15]. This is consistent with recent efforts to identify novel behavioural and biological markers of mild cognitive impairment (MCI) that can be used to inform choice of therapy and aid a personalized approach to clinical treatment [16; 17].

Mild cognitive impairment (MCI) is an intermediate state between normal aging and Alzheimer's disease. It is characterized by impaired memory performance or general intellectual function, more severe than normal aging, but not as severe as compared to patients with Alzheimer's disease [18-21]. The annual rate of progression from MCI to dementia is 5% - 10%. The cumulative rate is about 30% - 40%. Thus, 30 -40% of people with MCI eventually convert to dementia. This is substantially higher than the 1-2% for healthy older adults [22]. The incidence rates of MCI vary widely, depending on how this syndrome is categorized. However, best estimates are that the incidence of amnestic MCI subtypes range between 9.9 and 40.6 per 1,000 "person-years", and the incidence of non-amnestic MCI subtypes are 28 and 36.3 per 1,000 person-years [18; 20; 23].

Previous studies investigating MCI have focused primarily on cognitive [24; 25], memory [26], attention [27], and executive function deficits [28]. Additionally, people with MCI also have perceptual deficits. Previous research has provided evidence that people with MCI have difficulty in speech perception, a dichotic digit test [29; 30], as well as impaired visual motion perception [31]. However, to date, there is little research which has investigated the multisensory integration of older adults with MCI. One such study conducted by Wu, Yang, Yu, Li, Nakamura, Shen, et al. [32] investigated the audiovisual integration using a simple reaction time paradigm. They asked healthy controls (HC), MCI participants, and participants with Alzheimer's disease (AD) to indicate as quickly as possible when an attended stimulus was presented to the right or left of the fixation cross. They found neither significant differences in accuracy nor reaction times between HC and MCI. However, when examining the cumulative distribution function, they found that MCI participants violated the race model at later reaction times compared to HC. The race model is a reaction time measure of multisensory integration. A violation of the race model suggests that the effect is not due to a simple linear summation of the visual and auditory stimuli.

Healthy older adults tend to integrate more audio-visual information over a 'wider' temporal binding window (TBW) and spatial area compared to young adults [33-35]. The TBW is a span of time whereby information from the different sensory modalities is combined to form a single percept of an object. In an audio-visual temporal order judgement task, Setti et al. [36] found that young adults are able to accurately determine which stimulus was presented first (auditory or visual) when the stimulus onset asynchrony (SOA) was 70 ms or greater. However, older adults required an SOA greater than 270 ms to accurately determine which stimulus was presented first. This means that within the time span of 0 ms – 270 ms older adults were combining the auditory and visual stimuli and believed they were presented simultaneously. Using EEG they found that older adults exhibit smaller posterior P1 and fronto-central N1 components compared to the young adults. They suggested that these reduced components reflect a deficit in cross-sensory processing in the older adults.

Several other studies have used the sound-induced flash illusion (SiFi) to investigate the temporal dynamics of multisensory integration in older adults [33; 37]. The sound-induced flash illusion (SiFi) is an audio-visual illusion where a single flash is presented, along with two auditory beeps. Participants tend to perceive two flashes, if the two beeps are presented within a short temporal interval [e.g., 70 ms; 2; 3]. For young adults, if the SOA between the two beeps exceeds approximately 150 ms they will perceive one flash. Older adults will continue to perceive the SiFi at longer SOAs [33; 37]. Furthermore, older adults who are prone to falling perceived more illusions at longer SOAs, compared to healthy controls [33]. The "fallers" had normal unimodal visual and auditory perception. Setti et al. (2011) hypothesized that although the SiFi is unrelated to balance (participants performed the task while seated), the results indicate that the "fallers" overall have a reduced level of cortical connectivity between the sensory areas.

The SiFi is considered to be an early sensory illusion. EEG studies have demonstrated that the perceived illusion enhances early ERP components (starting ~30 ms) in the occipital lobe [38]. Using MEG, Keil, Müller, Hartmann, Weisz [39] found that the perception of the SiFi was modulated by increased beta-band activity (12 Hz - 21Hz) in the left middle frontal gyrus before the stimuli were presented. Using phase-locking coherence, Keil et al., found increased phase coherence between BA39, BA21, and BA18 in the beta-band for the perceived illusion trials. Beta-band activity is considered to be a top-down signal, sending information from higher-level areas to the early-sensory areas [40]. Keil et al., suggested that this increase in pre-stimulus beta-band activity shows an enhanced predisposition to integrate audio-visual information which is modulated at an inter-trial basis.

It is possible that the increased number of perceived SiFi, demonstrated in previous studies, is due to a difference in focused attention between older and younger adults. Older adults may have more difficulty in attending to a visual stimulus when an auditory stimulus is presented, thus their attention may switch to the auditory modality. DeLoss et al. [41] correlated performance in an auditory-only and visual-only Go/NoGo task to the number of perceived SiFi. They found that, in accordance to previous literature, older adults perceive more illusions. However, they found no difference between the age groups in the Go/NoGo tasks; suggesting that the increase in perceived illusions is not a product of increased distractor susceptibility or executive function [37].

While several studies have suggested that healthy older adults integrate more information of the different sensory modalities compared to younger adults; some research has suggested that age related cognitive disorder (such as: Alzheimer's disease) is related to a "connectivity breakdown" due to a "loss of structural and functional integrity of long cortico-cortical tracts" [42; see 43 for a review]. This breakdown can result in a decrease in multisensory integration. Furthermore, the superior temporal sulcus, one area responsible for multisensory integration is directly affected by Alzheimer's disease [50% loss of volume compared to healthy controls; 44]. More generally, it has been proposed that the dual role played by frontal and cerebellar degeneration and the disruption of fronto-cerebellar feed-back and feed-forward control loops may be of central importance for understanding age-related changes in: multisensory integration, the timing of information processing, processing speed, intra-individual variability of reaction times, and automaticity of cognitive functions [6; 45]. These losses in connectivity between brain regions as well as neuronal loss in the heteromodal areas can result in declined perceptual integration. These neuronal losses can have a significant behavioural impact. Delbeuck et al. [46] demonstrated that people with AD perceive fewer audiovisual McGurk illusions compared to the HCs, thus providing behavioural evidence for these neuronal losses.

The goal of the present study was to determine if older adults with MCI also integrate more audio-visual information, compared to healthy controls. We presented the SiFi to people with MCI and age and gender matched healthy controls (HC), with variable stimulus-onset asynchronies (SOAs) between the auditory stimuli. It is possible that MCI participants perceive fewer illusions compared to HC because of a decreased ability to integrate information from the auditory and visual modalities. Conversely, it has been demonstrated that the multisensory processing in MCI is more similar to HC than AD. Golob, Miranda, Johnson, and Starr [47] explored crossmodal interactions using EEG in healthy older adults, older adults with MCI, and those with AD. Golob et al. exploited a neuronal effect called the refractory period, whereby there is a reduction in a component's amplitude or latency due to the presentation of a previous stimulus [48]. When two stimuli were presented in a single modality (i.e., visual- or auditory-only), there was a reduction in the: P50, N100, and P200; when the second stimulus was presented, in all groups. However, when the auditory stimulus was followed by the visual stimulus, AD participants did not exhibit a reduction in ERP amplitude during the refractory period, compared to HC and MCI. HC participants experienced a reduced P50 component while MCI participants experienced reduced P50 and N100 components. These results suggest that people with AD have reduced cross-modal interactions compared to the HC and MCI groups. Taking these studies into account, it is possible that people with MCI have an increased TBW, compared to HC.

Methods

Participants

Fourteen older adults with mild cognitive impairment (10 males) between the ages of 65 years and 78 years and sixteen age-matched healthy older adults (10 males) took part in this experiment. Of the fourteen MCI participants, nine were diagnosed as amnestic MCI and the remainder non-amnestic MCI. The participants with MCI were recruited through the Goethe-University Memory Clinic. The MCI patients came to the Memory Clinic, complaining of subjective memory loss or cognitive decline, which was corroborated by a family member or close friend. The diagnose criteria of MCI was based on an impairment of at least one of the following cognitive domains: memory, language, visuospatial skills, executive function. This was assessed using the Consortium to Establish a Registry for Alzheimer's disease (CERAD), with a cut-off criterial of at least one standard deviation below the age norms. They were also given the Clinical Dementia Rating (CDR), with a score of 0.5.

None of the HC had a history of psychological disorder or report and sensory impairment. The MCI population also did not report any auditory or visual impairment. To ensure that the MCIs did not develop Alzheimer's Disease between the time of the initial diagnose and test, they were given a portion of the CERAD and the D2 test to characterize their mental state (see Table 1 for a list of CERAD results). The HCs were also given the CERAD and D2 to ensure that they did not have undiagnosed MCI. There was no significant difference in the years of education between the HCs (14.94 years) and MCI (15.7 years) ($\chi 2 = 8.28$, $p < 0.51$).

The ethics committee of the University of Frankfurt Medical Faculty approved this experiment.

Apparatus and Stimuli

The visual stimuli were presented on a 24" flat panel computer monitor. The visual stimulus was a white circular disk, subtending 2° of visual angle. This disk was placed 8° of visual angle below the fixation cross. The presentation duration of the disk was 16 ms.

The auditory stimulus consisted of a 16 ms, 3500 Hz pure tone with a total rise- and decay-time of 20 μs at a sound pressure level of 68 dBA. They were presented using closed, circum-aural headphones (AKG, Austria, model: K271) to reduce any ambient noise.

Design and Procedures

The CERAD was given to each participant before behavioural testing. This was done to ensure that the MCI participants did not develop Alzheimer's disease, but also to ensure that the older controls did not have undiagnosed MCI. The portions of the CERAD given to participants were: semantic fluency (animals), Boston naming test, mini-mental state, word learning, figure drawing and recall, phonemic fluency, and the Trail Making Tests A and B (see Table 1 for a list of results). The norms of the CERAD are adjusted for age, education level and sex.

The overall design of the experiment was based on a 3x7 Repeated Measures Design with Modality (vision-only, auditory-only, and audiovisual) and Stimulus-onset Asynchrony (SOA) as factors. The factor of Modality was blocked and the order randomized between participants. At the beginning of each trial a fixation cross was presented at the centre of the computer screen. Participants were instructed to maintain their eye gaze on the cross throughout the experiment.

In the vision-only block, one or two flashes were presented and the participants' task was to indicate how many flashes were presented. In the auditory-only block, one or two beeps were presented and the participants indicated how many beeps they heard. The SOA used in these blocks were: 0 ms (one stimulus event), 50 ms, 100 ms, 150 ms, 200 ms, 250 ms, 300 ms, 500 ms. In both blocks, a randomly permuted SOA was used when two stimuli were presented. There were 130 trials in each of the unimodal conditions, 60 trials where one stimulus was presented and the remaining trials where two stimuli were presented, with an equal number divided between the SOA conditions (10 trials in each remaining SOA condition).

The audio-visual block consisted of three conditions: two control conditions (1 beep/1 flash and 2 beeps/2 flashes) and the illusion condition (2 beeps/1 flash). In the control conditions, the auditory and visual stimuli were presented simultaneously. In the illusion condition, the visual flash was presented at the same time as the first auditory beep. In the 2 beeps/2 flashes and 2 beep/1 flash conditions, the SOAs used were 50 ms, 100 ms, 150 ms, 200 ms, 250 ms, 300 ms, 500 ms. These conditions were randomly presented within the block to avoid any response biases. The participants' task was to ignore the auditory stimuli and indicate how many visual flashes were presented. The audio-visual block contained 210 trials, with 70 trials within each condition.

All responses were made via a computer keyboard. It is possible that participants could perceive more than the presented stimuli (audio or visual), thus; responses were not restricted to "1" and "2". In less than 1% of trials, participants reported to have seen or heard three or more stimuli. While reaction times were recorded participants were asked to emphasize accuracy over speed. The experiment was programmed in Presentation (Neurobehavioral Systems, CA, USA).

Results

To examine the unimodal perception between the HC and MCI groups a 2x2x8 mixed-design ANOVA with Group (HC vs. MCI) as the between-subjects factor, and Modality (vision-only vs. auditory-only) and SOA (0 ms, 50 ms, 100 ms, 150 ms, 200 ms, 250 ms, 300 ms, and 500 ms) as the within-subjects factors. All analyses have been corrected for the lack of homogeneity of variance using the Greenhouse-Geisser method. There was no main effect of Group [$F(1,27) = 2.47$, partial eta-squared = 0.03, $p = 0.13$]. There was a main effect of Modality [$F(1,27) = 12.52$, partial eta-squared = 0.28, $p = 0.001$], with higher accuracy for the detection of the auditory stimuli (90.37%) compared to the visual stimuli (81.86%). There was also a main effect of SOA [$F(7,189) = 53.29$, partial eta-squared = 0.62, $p < 0.0001$]. Participants' accuracy increased as the SOA between stimuli increased (0 ms = 91.29%; 50 ms = 53.84%; 100 ms = 80.85%; 150 ms = 89.18%; 200 ms = 93.30%; 250 ms = 94.06%; 300 ms = 93.93%; 500 ms = 92.46%). There was a significant interaction between the factors of Modality and SOA [$F(7,189) = 3.17$, partial eta-squared = 0.09, $p = 0.034$] (see Figure 1). A Newman-Keuls posthoc test revealed participants were significantly worse when the SOA between the 2 flashes was 50 ms, compared to all other SOAs (*all p's* < 0.0005). There were no other significant interactions.

To examine the reaction times during unimodal perception the same analysis design was used. There was no main effect of Group [F(1,18) <1, n.s.]. There was also no main effect of Modality [F(1,18,) < 1, n.s.]. Finally, there was no main effect of SOA (F(7,126) = 1.6, p = 0.18]. There were no significant interactions between these factors.

----------------- Place Figure 1 about here ------------------

To examine the audiovisual interactions between the two groups we used a 2x3x7 mixed-measures ANOVA with Group (HC vs. MCI) as the between-subjects factor, and AV Stimuli (1-flash/1-beep vs. 2-flashes/2-beeps vs. 1-flash/2-beeps) and SOA (50 ms, 100 ms, 150 ms, 200 ms, 250 ms, 300 ms, and 500 ms) as the within-subjects factors. There was a main effect of Group [F(1, 33) = 9.55, partial eta-squared = 0.22, p = 0.004]. Overall, HC performance (85.36%) was significantly more accurate than MCI (76.28%). There was a main effect of AV Stimuli [F(2, 66) = 76.81, partial eta-squared = 0.70, p < 0.0001]. Participants were significantly more accurate in the control conditions (1 beep/1 flash = 93.74%; 2 beeps/2 flashes = 94.56%) compared to the illusion condition (54.15%). There was also a significant main effect of SOA (50 ms = 71.73%; 100 ms = 73.42%; 150 ms = 61.61%; 200 ms = 83.56%; 250 ms = 82.94%; 200 ms = 83.71%; 500 ms = 88.77%) [F(6,198) = 10.24, partial eta-squared = 0.24, p < 0.0001]. There was a significant interaction between the factors of Group and AV Stimuli [F(2,66) = 5.213, partial eta-squared = 0.14, p = 0.026]. There was also a significant interaction between AV Stimuli and SOA [F(12,396) = 8.98, partial eta-squared = 0.21, p < 0.0001]. There was no significant three-way interaction.

Using a Mann-Whitney non-parametric test between the two groups, there was a significant difference between the HC and MCI groups in the 1 beep/1 flash 200 ms (Z = -2.92, p = 0.003) and 1 beep/1 flash 300 ms (Z = -2.56, p = 0.01) conditions, with MCI participants being significantly worse than HCs. Importantly, MCI participants perceived significantly more illusions in the 2 beeps/1flash condition when the SOA between the two beeps was 150 ms ($Z = -3.38$, $p = 0.0007$), 250 ms ($Z = -2.60$, $p = 0.009$), and 300 ms ($Z = -2.58$, $p = 0.01$) (see Figure 2A).

To examine the reaction times during multisensory perception the same analysis design was used. There was no main effect of Group [$F(1,11) < 1$, n.s.]. There was a main effect of AV Stimuli [$F(2,22) = 5.00$, $p = 0.027$]. Participants were significantly slower in the 2 beeps/1 flash (illusion) condition (1246.22 ms) compared to the 2 beeps/2 flashes (1136.91 ms) and 1 beep/1 flash conditions (1074.20 ms). There was also a significant difference between these two AV control conditions (all ps < 0.05). There was also a significant main effect of SOA (50 ms = 1237.40 ms; 100 ms = 1214.76 ms; 150 ms = 1164.58 ms; 200 ms = 1133.08 ms; 250 ms = 1103.30 ms; 300 ms = 1138 ms; 500 ms = 1075.91 ms) [$F(6,66) = 6.078$, $p = 0.001$]. Participants responded more quickly as the SOA between the two stimuli increased. There was a significant interaction between AV Stimuli and SOA. Participants were significantly faster in the 2 beeps/1 flash condition when the SOA between two beeps was 500 ms, compared for the other SOAs (all ps < 0.001). There was no significant difference between the SOAs in the 1 flash/1 beeps and 2 flashes/2 beeps conditions. There was a significant interaction between AV Stimuli and Group [$F(2,22) = 9.99$, $p = 0.003$]. The MCI participants (1388.06 ms) were significantly slower in the 2 beeps/1 flash condition, compared to the HC (1076.47 ms). There were significant differences between the two groups in the 1 beep/1flash and 2 beeps/2 flashes conditions (see Figure 2b). Although, there was a trend in the 1 beep/1 flash condition for longer reaction times for the MCI participants (1125.76 ms) compared to the HC (976.14 ms; $p = 0.052$). There was no significant interaction between SOA and Group [$F(6,66) = 1.79$, $p = 0.160$]. Finally, there was no significant three-way interaction between these factors.

A Mann-Whitney non-parametric test between the two groups revealed that MCIs were significantly slower than HCs in the 1 beep/1 flash condition when the SOA was 200 ms ($Z = -2.92$, $P = 0.003$) and 300 ms ($Z = -2.56$, $p = 0.01$). In the 2 beep/1 flash (illusion) condition MCIs were significantly slower than HCs when the SOA between the two beeps were 150 ms ($Z = -3.38$, $p < 0.0005$), 250 ms ($Z = -2.6$, $p < 0.01$), and 300 ms ($Z = -2.58$, $p < 0.01$).

------------------ Place Figure 2 about here ------------------

Discussion

MCI is only characterized by a person's performance in cognitive tasks. However these data, as well as previous studies [32], have demonstrated that people with MCI also show behavioural differences in early sensory integration processing, compared to HC. These findings revealed, participants with MCI perceived more SiFi compared to healthy controls. MCIs perceived more illusions, across a broader range of auditory SOAs compared to HC. This suggests that not only are MCIs more likely to integrate audio-visual information, compared to controls; MCIs also integrate audio-visual information across a 'wider' temporal binding window than controls. There was no significant difference between the two groups in the 2 beeps/1 flash condition when the SOA between the auditory stimuli was 500 ms; suggesting that the results are not due to a difference in understanding the task. These results suggest that this SiFi behavioural task is sensitive to delineate between healthy older adults and those older adults with mild cognitive impairment.

In order to determine whether the behavioural differences in the SiFi are associated with a specific cognitive deficit we performed a correlational analysis between the different sections of the CERAD compared to their individual behavioural performance. We did not find any significant correlation between the SiFi and any subsection of the CERAD in the MCI and older adults groups. It appears that the SiFi is not related to a particular cognitive decline but to the overall deficit. Perhaps this is not surprising, given that the SiFi is known to be an early sensory process [38].

It is possible that the difference in the number of perceived illusions between the groups is related to differences in unisensory acuity. This may result in a modulation of the perceived reliability (maximum likelihood estimate) between the auditory and visual signals. For example, if participants were not able to accurately determine the number of perceived visual flashes, but accurately determine the number of beeps, participants will rely more on the auditory modality than the visual modality. However, there was no significant difference between the groups in the two unimodal conditions.

The sound-induced flash illusion has been used to find differences in multisensory integration in healthy older adults compared to young adults, healthy older adults compared to older adults prone to falling, children with ASD compared to healthy age-matched controls, and now people with MCI compared to healthy controls. This relatively simple behavioural paradigm is a powerful tool that can potentially be used to assess the cortical connectivity between sensory regions. According to Keil et al. (2013), the SiFi is regulated by pre-stimulus beta-band activity, in young adults. Beta-band activity is thought of as a correlate of top-down information transfer [49-51]. Using phase-locking values, Keil et al. found increased connectivity for trials in which the illusions were perceived, between the areas of the left middle temporal gyrus and the primary visual and auditory areas. EEG beta-band activity in the occipital lobe has been implicated in increased arousal and visual attention [see 49 for a review; 50; 52]. However, people with MCI do not exhibit such significant changes in beta-band activity [53]. Beta-band activity is also critical for the integration of audio-visual stimuli [54]. Given that the SiFi is modulated by pre-stimulus beta-band activity [39], it is possible that the participants with MCI had less modulation of their inter-trial beta-band activity, resulting in the perception of more illusions, compared to HCs.

It has been demonstrated that healthy older adults with decreased unisensory perception also have increased cognitive decline [1; 55]. It could be that the cognitive decline is simply the result of increased sensory noise. Baltes and Lindenberger [1] suggested that cognitive decline is not the result of increasingly noisy signals but due to a breakdown of a cortical network that is common to both sensory perception and fluid intelligence; however, they do not propose candidate brain regions. More recently, Melnick, Harrison, Park, Bennetto, and Tadin [56] behaviourally demonstrated that the link between sensory acuity and fluid intelligence [see 57; 58 for a link between fluid intelligence and working memory] may not be due to a common neural framework, but correlated with an individual's overall ability inhibit surrounding (irrelevant) information.

It is possible that the perceptual differences are due to differences in ‘processing speed’ [59; 60]. Deary et al. [60] have demonstrated that visual information processing is correlated with general intelligence. However, it is unlikely that processing speed is the sole reason for MCIs perceiving more illusions than HCs. Melnick et al. [56] demonstrated in young healthy controls that processing speed (and intelligence) cannot entirely account for visual perception in a discrimination task. Visual perception performance was also correlated with poor stimulus inhibition. While MCIs can have high general intelligence, it is also possible that they exhibit a reduced ability to suppress irrelevant information.

Our results extend the findings of Melnick et al. by suggesting that it is the MCIs’ inability to supress irrelevant auditory stimuli results in the increased perception of illusory flashes. There are common brain areas used in both the processing of working memory and the SiFi. Increased beta-band power in the left middle frontal gyus (BA9) as well as BA4 of the parietal cortex has been associated with SiFi perception [39] and working memory [as well as bilateral dorsolateral prefrontal cortex and inferior parietal cortex-BA 40/7; 58]. This does not suggest that there is a common network for both the SiFi and working memory but there are some common brain areas involved in both tasks.

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Acknowledgements

This study was supported by the Hessian initiative for the development of scientific and economic excellence (LOEWE) Neuronal Coordination Research Focus Frankfurt (NeFF).

Table 1.

Table 1: The mean CERAD results from each group. The values represent the average score for each section. The numbers in parentheses represent the standard error of the mean.

CERAD results

		HC	MCI
Semantic Fluency (animals)		23.69 (0.69)	15.25 (1.12)
Boston Naming Test		14.54 (0.89)	13.5 (0.87)
Mini- Mental State		29.23 (0.25)	27.5 (1.2)
Verbal Learning	Immediate Recall (total)	22.38 (0.75)	15.75 (1.39)
	Delayed Recall	8.23 (0.64)	5.5 (1.15)
Constructional Praxis	Drawing	10.54 (1.02)	10.75 (0.55)
	Replicate drawings	10.08 (0.99)	9 (1.07)
	Savings	0.96 (1.01)	0.83 (0.87)
Word Fluency		18.23 (0.51)	9.25 (1.08)
Trail Making Test	Part A	35.46 (1.14)	40.5 (0.99)
	Part B	84.54 (1.33)	163.75 (1.33)
	Part B/A	2.52 (1.26)	4.2 (1.09)

Figure Captions.

1) Results from the visual-only and auditory-only blocks. Both groups were more accurate when determining the number of beeps, compared to flashes. In both modalities, participants were more accurate as the SOA between stimuli increased. There was no significant difference between groups. The error bars represent the SEM.
2) A) This graph illustrates the mean accuracy from the multisensory conditions. There were no group differences in the control conditions (1 beep/1 flash & 2 beeps/2 flashes). MCI participants perceived more illusions, across a wider range of SOAs, compared to HC. The error bars represent the SEM. B) The mean reaction times in the multisensory conditions. MCI participants took significantly longer in the 2 beeps/1 flash condition, compared to HCs.

Figure 1.

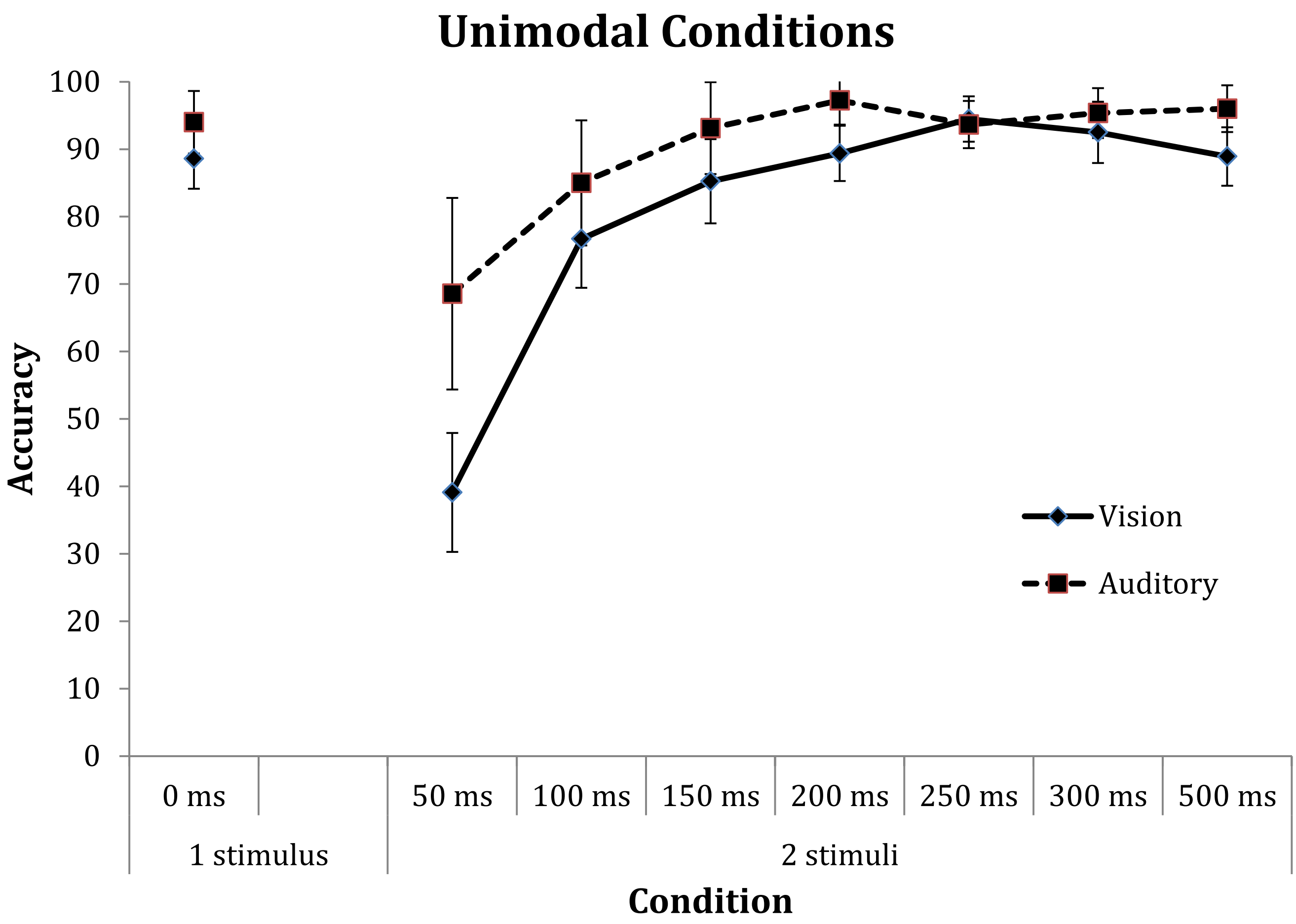
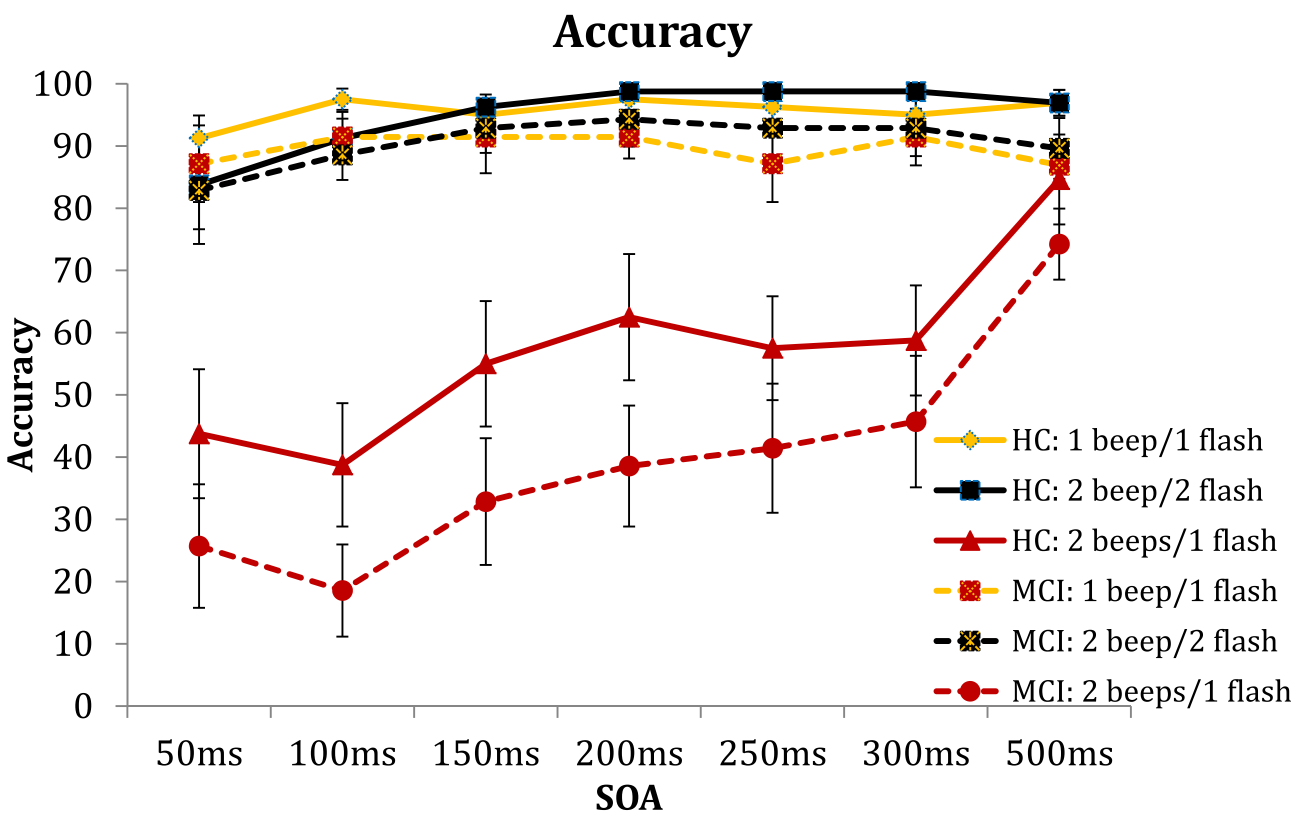
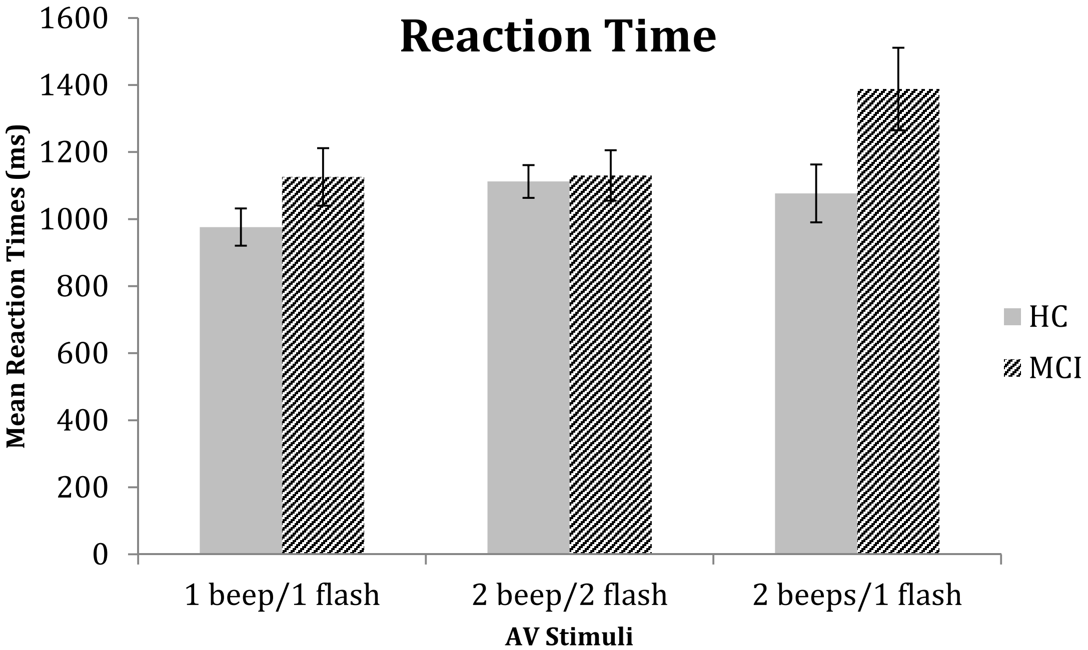

Unimodal Conditions
Accuracy
100
90
80
70
60
50
40
30
20
10
0
0 ms
50 ms
100 ms
150 ms
200 ms
250 ms
300 ms
500 ms
1 stimulus
2 stimuli
Condition
Vision
Auditory

Figure 2.

A)


Accuracy
100
90
80
70
60
50
40
30
20
10
0
Accuracy
HC: 1 beep/1 flash
HC: 2 beep/2 flash
HC: 2 beeps/1 flash
MCI: 1 beep/1 flash
MCI: 2 beep/2 flash
MCI: 2 beeps/1 flash
50ms
100ms
150ms
200ms
250ms
300ms
500ms
SOA

B)


Reaction Time
1600
1400
1200
1000
800
600
400
200
0
Mean Reaction Times (ms)
HC
MCI
1 beep/1 flash
2 beep/2 flash
2 beeps/1 flash
AV Stimuli