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Mechanisms of visuospatial orienting in deafness

J. M. Colmenero
Universidad de Jaén, Spain

A. Catena
Universidad de Granada, Spain

L. J. Fuentes
Universidad de Almería, Spain

M. M. Ramos
Universidad de Jaén, Spain

The aim of this work was to explore the nature of elementary operations (engage, move, disengage, and filtering) of spatial attention in deaf experts in sign language. Good communication skills require deaf people to rapidly change attention to at least two separate spatial locations, the facial expression and the hand signs of the speaker. Overtraining imposed by sign language demands might have modified certain characteristics of the spatial attention operations. To test that, a spatial orienting task was used in two experiments. Experiment 1 showed that deaf subjects reoriented their attention to the target location faster than hearing subjects in invalid trials. Experiment 2 indicated that inhibition of return decays faster in deaf than in hearing people. These results suggest that deaf subjects can disengage their attention faster than hearing subjects, fostering search of relevant information in more spatial locations.

This study focused on the functioning of some elementary operations of spatial attention in deaf persons. There are several important factors that may contribute to a differential development of spatial attention in deaf compared to normal hearing people. First, deaf and hearing people interact with their environment in different ways. Interpersonal communication between deaf people is mainly

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Correspondence should be addressed to J. M. Colmenero, Departamento de Psicología, Facultad de Humanidades y CCEE, Universidad de Jaén, 23071 Jaén, Spain. Email: jjimenez@ujaen.es

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done on the basis of sign languages in which the majority of manual signs appear in the periphery of the visual field (Bellugi & Klima, 1975; Parasnis & Samar, 1982; Rodríguez Gonzalez, 1992; Siple, Hartfield, & Caccamise, 1978). Sign languages also require attending directly to the emitter's face, because hand signs meaning depends on both his or her facial expression and lips movements. Therefore, sign languages demand a rapid change of attention between relatively distant locations in the visual field.

Rapid changes of attention are also necessary in their daily life. For instance, deaf people have to identify and recognise peripheral visual signs when they are engaged in a conversation while walking or driving (Swisher, 1993). Thus, quick detection of visual peripheral stimulation is crucial for deaf people to communicate. It is reasonable to think, then, that deaf people might have developed spatial attentional skills in greater extension than normal hearing people in order to cope effectively with everyday situations.

However, experimental evidence on attentive compensatory skills in deaf people is controversial. Early work on this topic employed visual-perceptual tasks as part of nonverbal tests, such as the Nebraska Test of Learning Aptitude (Templin, 1950) or the Raven's Progressive Matrices (Hiskey, 1956; Oléron, 1950; for reviews, see Colmenero, Catena, & Fuentes, 2000; Parasnis, 1983). Results of these studies suggest that deafness impaired some cognitive abilities like abstract reasoning, analogy, memory, and symbolic thinking (Levine, 1958; Myklebust & Brutten, 1953; Suchman, 1966; although see Hayes, 1955; Larr, 1956), but no benefits in perceptual or attentional skills were observed. The lack of compensatory visuospatial or attentional skills in hearing-impaired people of previous studies seems to reflect a sort of methodological deficiencies mainly related to some characteristics of the hearing-impaired subjects that participated in the experiments such as the amount of hearing loss, etiology, and onset of deafness, language(s), and/or mode(s) of communication (see, for example, Hoemann, 1978; Reynolds, 1978, 1987, 1993).

More recent work, nonetheless, suggests that the auditory deficit may induce specific compensatory changes in the attentional and/or perceptual processing of peripheral visual stimuli (Burnstine, Greenough, & Tees, 1984; Neville, 1988; Swisher, 1993). In this line, Neville, Schmidt, and Kutas (1983) recorded ERPs in several cortical areas of both normal hearing and congenitally deaf subjects while they had to detect a white square appearing either foveally or 8° to the left or right from fixation. The results showed that the auditory cortical areas participated in the processing of visual peripheral stimuli only in congenitally deaf subjects. In similar studies, Neville and Lawson (1987a, 1987b, 1987c) recorded ERPs and reaction times (RTs) when subjects were told to detect the direction of movement of a white square appearing either foveally or 18° to the left or right from fixation. Three groups of subjects—normal hearing, congenitally deaf, and normal hearing with deaf parents—were asked to attend either to the left, right or foveally, while maintaining a centred gaze. The results showed greater negative amplitudes (N1) in areas of the superior parietal cortex in both congenitally deaf and hearing people with deaf parents than in normal hearing subjects. The authors concluded that N1 differences were due to the special capability of deaf people, acquired during the learning of a visual sign language, to detect peripheral visual stimuli. Note that greater N1 amplitude in hearing subjects with deaf parents could be due to these people using sign language regularly to communicate with their parents. Thus, the increased ability to detect peripheral visual stimuli seems to be associated with learning or using sign language not with hearing impairment *per se*.

Even more recently, Bavelier et al. (2000) have observed that congenitally deaf people show more activity than normal hearing people in visual areas linked to motion perception (area MT) only when they searched for changes in stimuli at peripheral locations of the visual field. Also, effective connectivity (neural connections between MT and the parietal cortex) was stronger in deaf than in hearing individuals during peripheral but not central attention. Thus, enhanced peripheral attention (faster RTs to peripheral stimuli, Neville & Lawson, 1987a, 1987b) observed in deaf people may be mediated by alterations of the connectivity between MT and the parietal cortex, one of the main areas for spatial attention. Bavelier, Brozinsky, Tomann, Mitchell, Neville, and Liu (2001) have also claimed that deaf people show enhanced sensitivity of visual orientation mechanisms and can devote more resources to the processing of visual cues because these subjects can only use visual cues to locate information in space.

Although Neville and Lawson's (1987a, 1987b, 1987c) studies clearly indicate that spatial attention functioning of deaf people shows differences compared with normal subjects, it is an open question to determine what attentional operations are changed by learning a visual sign language. It has been assumed that when attention has to be allocated to a new object in the visual field a set of orchestrated operations are involved. These operations refer to the disengagement of attention from its current location, movement of the attentional focus to the new location, engagement of its focus to the selected location, and filtering irrelevant information (for a review, see Posner & Raichle, 1994). What of these elementary operations are actually improved in the process of learning a visual sign language? To our knowledge, only a few authors have addressed this important question. Parasnis and Samar (1985) compared the performance of normal hearing and congenitally severe deaf subjects while discriminating the location of a target stimulus (a black circle). In their study each trial began with a fixation point followed by either a central cue (an ''arrow'' pointing to the left or to the right) or a noninformative neutral cue (a ''plus'' sign). Then, the target appeared either to the right or the left of the fixation point with an eccentricity of 2°. The central arrow indicated the correct location of the target in 80% of trials (valid trials). There were two load conditions: *foveal load* and *nonfoveal load* conditions. In the foveal load condition, five crosses were presented to the fovea simultaneously with the peripheral target. Subjects were instructed to ignore this foveal stimulus. In the nonfoveal load condition, only the peripheral target was presented. The results in the nonfoveal condition showed that hearing and deaf subjects oriented their attention similarly in valid trials. Also, in the foveal load condition, interference effects from the foveal irrelevant stimulus were similar in both groups. These results suggest that filtering, moving, and engaging attention to a cued location are similar in both hearing and deaf people. The more interesting result was that deaf people responded faster than hearing subjects in invalid trials but only in the foveal load condition. Parasnis and Samar concluded that deaf people can reorient (move) their attention from the periphery more efficiently than hearing people *only* in the presence of distracting foveal stimulation.

Parasnis and Samar (1985) argued that the differences between hearing and deaf people in invalid trials could be due to the similarities of this condition to everyday situations of deaf people. However, Parasnis and Samar's foveal load condition is far from real-life situations because deaf people usually have to attend both to foveal and peripheral stimuli at once, whereas in their experiment subjects had to ignore the foveal information.

The main purpose of the present work is to assess if normal hearing and deaf people differ in some of the basic operations involved in orienting attention to spatial locations.

EXPERIMENT 1

As Parasnis and Samar (1985), we examined both facilitatory and inhibitory effects of orienting attention to visual stimuli presented far away from the fovea. However, in the present study, we used peripheral informative cues and a simple detection task instead of central cues and a location discrimination task used by Parasnis and Samar because in our view, this kind of cue and task would allow us to better assess the basic operations involved in orienting attention (cf. Posner, 1980).

Method

Subjects. Twenty-seven hearing and seventeen deaf subjects (mean age 22, ranging from 18 to 30 years) participated in this experiment. Deaf subjects were paid. Hearing subjects were students at the University of Jaén and received extra course credit for their participation. The deaf subjects suffered from deep neurosensorial deafness (due to an alteration in the transduction at inner ear) and they had all hearing parents. Three were congenitally deaf, due to inheritance or to maternal pathologies during gestation (for example, rubella). The remaining deaf subjects became deaf after different illness or postnatal mishap (earache, tonsillitis, meningitis). All the deaf subjects were prelocutive (they became deaf before learning oral language) and had been employing the Spanish Sign Language (SLS) for at least 10–15 years (mean of 12 years). The deaf subjects had coursed only primary studies. None of the participants presented any other type of relevant anomaly. All subjects had normal or corrected-to-normal vision.

Stimuli and materials. Subjects sat 30 cm from the computer screen, and put their head on a chinrest. The experiment was carried out in a dimly lit room to optimise the visual contrast of stimuli. Several IBM-compatible personal computers were employed. The computers controlled stimulus presentation and temporal parameters of trials, and subjects' responses were registered through the computer keyboard. Stimuli were white alphanumeric characters displayed in a black background on the computer screen, controlled by an SVGA card. There were three types of stimuli (all about 5 mm height by 4 mm width). The low marks (_) were located at 10.9 cm (20°) to the right and the left of central fixation, and remained on throughout the experiment. A vertical mark (|) appearing either over the left or the right mark served as the peripheral cue. An ''O'' displayed over the left or the right low mark served as the target stimulus. On valid trials, the cue and the target appeared in the same location, whereas in invalid trials both appeared in different locations. In neutral trials, two cues appeared simultaneously over both low marks. These different kind of trials served to compute both benefits (RTs in neutral trials minus RT in valid trials) and costs (RT in neutral trials minus RT in invalid trials).

Design and procedure. Subjects were told to press a key whenever the target appeared either to the left or the right of fixation. Speed and accuracy in responding were both stressed in the instructions. They were encouraged to keep their gaze at fixation during the whole session. An SLS interpreter explained the instructions to the deaf subjects. Each trial began with the presentation of the fixation point (*), located in the centre of the screen, and the two low marks, located left and right of fixation (Figure 1). The fixation point remained on for 500 ms. Then, after a blank interval of 500 ms, a peripheral 100 ms cue was displayed followed by the target. Cue–target onset asynchrony (SOA) was manipulated at 125, 150, 175, 200, and 250 ms. The intertrial interval was 1200 ms.

Trials were divided into five blocks: one practice block (60 trials) followed by four experimental (150 trials each) blocks. In the experimental blocks, there were 80 valid, 50 neutral, and 20 invalid trials. In half of the trials the target appeared to the right and to left in the other half. There were 20% of trials for each SOA condition. The sequence of trials within each block was random. The factorial crossing of two levels of hearing status by three levels of cue validity by five levels of SOA produced a total of thirty experimental conditions. There were two trials of each condition in the practice block.

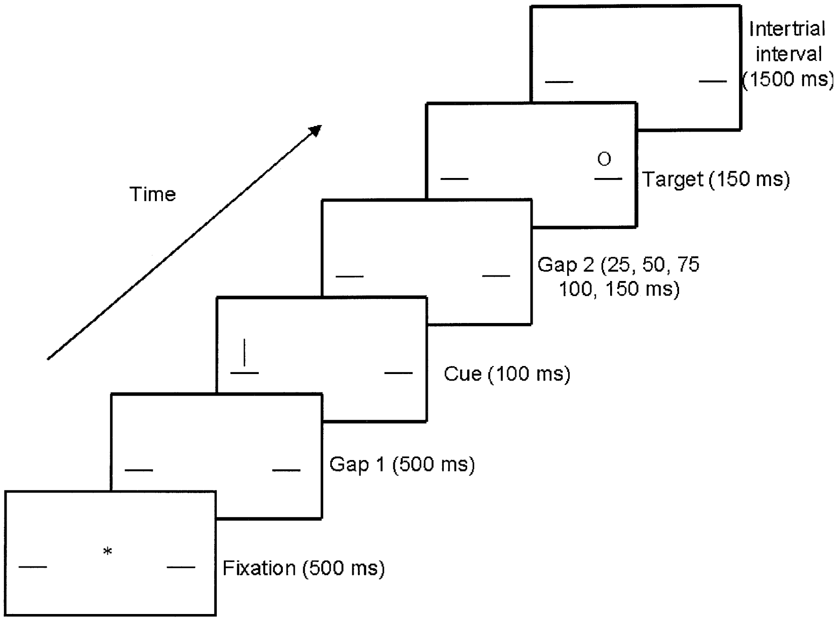

Figure 1. Example of the sequence of events in Experiment 1. In this example the cue is invalid.

Results

Means of RTs for correct responses were computed for each experimental condition, excluding times below 120 ms and above 1000 ms. Less than 2% of trials (range: 1.4–1.9%) were discarded using this trimming cut-off. Given such a low percentage of errors, they were not analysed further. A significance level of .05 was used for all statistical decisions.

Correct responses were analysed through a mixed variance analysis (ANOVA) with hearing status (deaf, hearing) as the between-groups factor, and cue validity (neutral, valid, invalid) and SOA (125, 150, 175, 200, and 250 ms) as the within-subject variables. The main effects of hearing status, $F(1, 42) = 4.08$, $MSE = 71753.74$, $p < .05$, cue validity, $F\ (2, 84) = 41.776$, $MSE = 1505.62$, $p < .00001$, and SOA, $F(4, 168) = 41.536$, $MSE = 1031.27$, $p < .00001$ were significant. Deaf subjects detected targets faster than hearing subjects (239 and 282 ms, respectively). The validity effect showed attentional costs: faster RTs to neutral than invalids trials, $F(1, 42) = 58.9$, $MSE = 1471.27$, $p < .00001$, but not attentional benefits (the neutral and valid conditions did not differ from each other, $F < 1$). The validity effect was significant, that is, RTs were faster in the valid than in the invalid condition, $F(1, 42) = 42.9$, $MSE = 2360.7$, $p < .00001$. In general, RTs decreased as SOA increased from 125 to 175 ms, but higher SOAs did not improve performance.

Only the Hearing status × Validity interaction was significant, $F(2, 84) = 9.315$, $MSE = 1505.62$, $p < .001$. Figure 2 shows this interaction. The analysis of

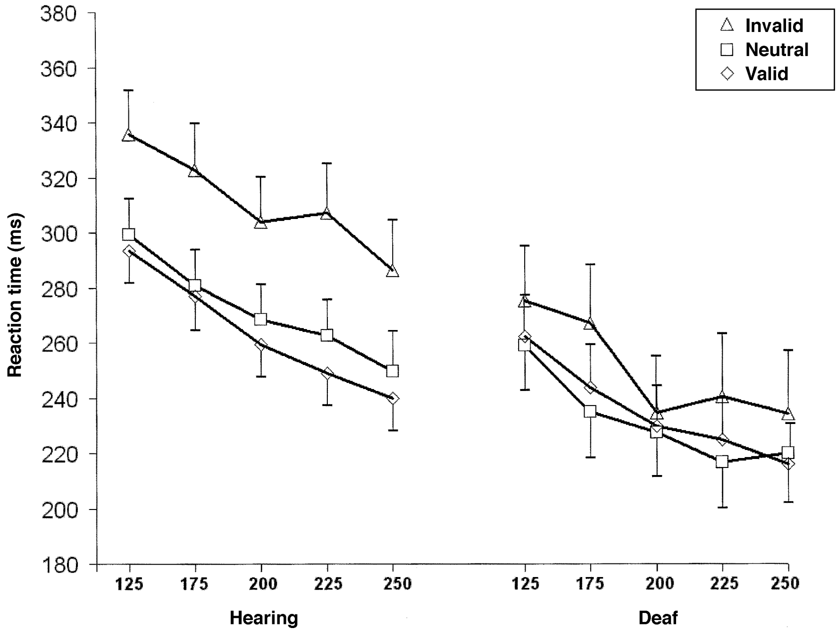

Figure 2. Mean reaction times according to hearing status, SOA, and cueing condition of Experiment 1. Vertical lines indicate mean standard errors.

the simple effects revealed benefits, *F*(1, 26) = 7.71, *MSE* = 126.57, *p* < .00001, and costs, *F*(1, 26) = 63.89, *MSE* = 320.96, *p* < .00001, in the hearing subjects, but only costs in the deaf ones, *F*(1, 16) = 11.84, *MSE* = 251.22, *p* < .01.

Additional separate ANOVAs were performed to compare the size of benefits and costs between deaf and hearing subjects at the five levels of SOA. Benefit (neutral RTs minus valid RTs) and cost (neutral RTs minus invalid RTs) scores were first calculated for each subject, and then entered into a 2 × 5 ANOVA with hearing status (hearing, deaf) as the between-groups factor and SOA (125, 150, 175, 200, and 250 ms) as the within-subject factor. The analysis of benefits scores showed that only the main effect of hearing status was significant *F*(1, 42) = 5.6085, *MSE* = 1369.7, *p* < .05, showing greater benefits for hearing subjects (8.42 ms) than for deaf subjects (−3.70 ms). Similarly, the analysis of costs scores showed only a significant main effect of hearing status, *F*(1, 42) = 7.316, *MSE* = 21530.53, *p* < .01, showing more costs for hearing (−38.98 ms) than for deaf subjects (−18.66 ms).

Discussion

The results of this experiment shows that deaf people detect targets faster than hearing subjects, irrespective of cue–target SOA and cue validity. Colmenero, Catena, and Fuentes (1998) found a similar result using central symbolic cues rather than peripheral ones. Taken together, these results indicate that elementary operations of spatial attention are faster in deaf than in hearing people, probably due to a higher activation level induced by the cues (Posner & Boies, 1971). However, it is also possible to attribute the faster detection of peripheral stimuli showed by deaf people to an increased sensitivity to visual peripheral stimuli in this group of subjects.[1]

The two main results of this experiment are the lack of benefits in the deaf group and lower costs observed in deaf compared to hearing subjects. The reduced costs in deaf subjects could be due to a faster movement of attention to the target location. But, if that were true, it would have also produced larger benefits in deaf than in hearing subjects. Apparently the lack of benefits showed by the deaf subjects would go against that account. Alternatively, the pattern of validity effects showed by the deaf subjects (no benefits, reduced costs) is better explained by a greater ability to disengage attention from the current location. The quick disengaging of attention from the cued location fosters the return of attention to the centre before the target onset, eliminating benefits. In agreement with this interpretation is the fact that although the comparisons did not reach statistical significance, deaf people showed systematically longer RTs in valid than in neutral trials throughout the five SOAs, suggesting a tendency to costs in valid trials rather than lack of benefits being due to a possible floor effect. Concerning the invalid trials, the quick disengaging of attention from the cued location would short the time needed to reach the target at the other location, producing less costs.

The validity effects observed in the deaf group are consistent with the ability of these people to attend to different objects in their everyday visual environment, in which they have to process both face and hand signals to communicate with others. A way to meet this requirement is to have an increased capacity to disengage attention from attended locations and maybe an earlier resolution of any inhibitory mechanism that can be deployed to avoid re-exploration of recent attended locations. Experiment 2 addressed this second potential capacity of deaf people in an inhibition of return paradigm.

EXPERIMENT 2

In a visual orientation task like that used in Experiment 1, it has been consistently found that benefits produced by a peripheral cue decline as cue–target SOA increases (Posner & Cohen, 1984). In fact, it has been observed longer RTs to cued than to uncued targets (the inhibition of return effect; IOR) when cue–target SOAs larger than about 250 ms and uninformative cues are used (Posner, Choate, Rafal, & Vaughn, 1985). IOR has an obvious adaptive role, because

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[1] We acknowledge P. Butcher for this comment.

looking for relevant information (e.g., foraging behaviour) optimises when searching for novel locations, remembering informative locations, and avoiding irrelevant already explored locations (see Klein, 2000, for a review). With deaf people things can be different. As we mentioned above, deaf people must change attention in the visual field quicker and more frequently than hearing individuals, i.e., between the speaker's face and hand. In a very short time, an irrelevant attended location can become relevant because a hand sign or a lip gesture may occur there. Thus, returning soon to an already explored location might prove an advantage rather than an inconvenience. In other words, adaptive behaviour in deaf people might require the speaker's hand and face not being ignored for a long time. Then, we should expect IOR in deaf subjects to be resolved in cue–target SOAs where hearing people usually show the effect.

In this experiment we used two cue–target SOAs, 350 and 850 ms in a similar procedure to that used by Abrams and Dobkin (1994), in which the same stimulus is displayed at fixation and at a peripheral location. We chose this procedure because it is very close to the visual environment of deaf people, where potentially relevant stimuli can appear at fixation (the speaker's lips) or in the periphery (the speaker's hand). We expected deaf and hearing subjects to show similar IOR in the shorter, but not in the longer, SOA.

Method

Subjects. Seventeen hearing and eleven deaf subjects of similar characteristics to those of Experiment 1 participated in this experiment.

Stimuli and procedure. The stimuli were similar to those of Experiment 1 with the following differences. The peripheral locations of markers (‘‘_’’) were located at 14º left and right from fixation, and the cue was the letter ‘‘X’’. The letter ‘‘O’’ served as the fixation point when it was presented at the centre position, and as the target when it appeared at a peripheral location (see Abrams & Dobkin, 1994).

Figure 3 shows a typical trial of the present experiment. In each trial letter ‘‘O’’ and markers were presented for 1000 ms. Then, the cue appeared for 100 ms either to the right or the left from fixation along with the centred ‘‘O’’. The ‘‘O’’ remained alone at fixation and was then replaced by the cue after 100 or 350 ms, according to the cue–target SOA value. After this interval, the ‘‘O’’ replaced the central cue for 50 ms, and then the target appeared either to the cued or the uncued location for 150 ms. Thus, the SOA between the peripheral cue (the ‘‘X’’) and the peripheral target (the ‘‘O’’) could be either 350 or 850 ms. The SOA was 350 ms for half of trials, and 850 ms for the other half in a random order. In the valid trials, target and cue were displayed at the same peripheral location, and at opposite locations in the invalid trials. The intertrial interval was 1750 ms.

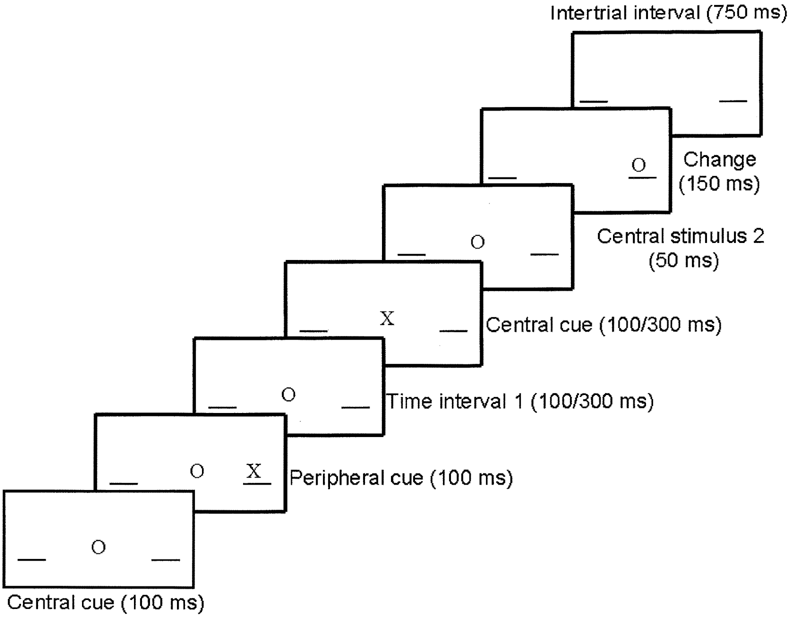

Figure 3. Example of the sequence of events in Experiment 2. Figure shows an example of a valid trial.

There was one practice block (40 trials), and four trials experimental blocks (120 trials each). In each block the target was displayed to the left in half of trials and to the right in the other half. Also, half of the trials were valid (50% in each SOA) and invalid trials the other half (50% in each SOA). Subjects were told that they had to press a key as quickly and accurately as possible only when the target ''O'' appeared at any of the two peripheral locations. Also they were encouraged to fix their gaze at the screen centre.

Results

RTs below 120 ms and above 1000 ms were discarded for the statistical analyses. Less than 2% (range: 1.3–1.9%) of trials were discarded using this trimming cut-off and they were not further analysed.

Mean RTs for correct responses are shown in Figure 4. Data were analysed through a mixed factorial ANOVA, with hearing status as the between-subjects factor (deaf, hearing), and cueing (valid, invalid) and SOA (350 and 850 ms) as within-subjects factors. The main effects of cueing, $F(1, 26) = 24.81$, $MSE = 155.88$, $p < .0001$, and SOA, $F(1, 26) = 137.42$, $MSE = 48.75$, $p < .000001$, were significant. The two-way interactions: Hearing status × Cueing, $F(1, 26) = 14.65$, $MSE = 155.88$, $p < .001$, Hearing status × SOA, $F(1, 26) = 10.59$, $MSE =$

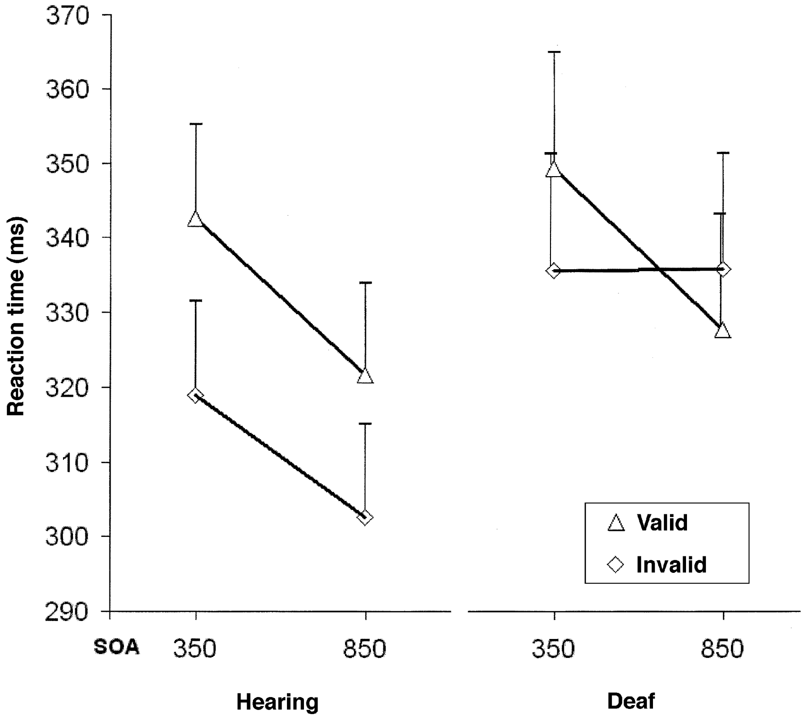

Figure 4. Mean reaction times according to hearing status, cueing condition, and SOA in Experiment 2. Vertical lines indicate mean standard errors.

41.75, $p < .01$, and Cueing × SOA, $F(1, 26) = 27.76$, $MSE = 42.31$, $p < .0001$, were all significant.

However, these interactions were modulated by the significant Hearing status × Cueing × SOA interaction, $F(1, 26) = 11.42$, $MSE = 42.31$, $p < .01$. The further analysis of the three-way interaction showed that, in the hearing group, RTs were longer for the valid than for the invalid trials (IOR effect) in both the 350 and 850 ms SOAs, $F(1, 16) = 46.31$, $MSE = 103$, $p < .0000001$, and $F(1, 16) = 31.21$, $MSE = 97$, $p < .0001$, respectively. However, according to our predictions, deaf subjects had significantly longer RTs in the valid than in the invalid trials (IOR effect) just in the short SOA, $F(1, 10) = 11.34$, $MSE = 91$, $p < .001$, but showed shorter RTs in the valid compared to the invalid trials in the long SOA, although that effect was only marginally significant, $F(1,10) = 3.45$, $MSE = 105$, $p = .09$.

Discussion

Our results in the hearing group replicated the standard IOR usually found when the cue–target SOA is longer than 250 ms. However, in deaf people IOR was found only with the short but not with the long SOA, suggesting that IOR time course in deaf and hearing people is rather different. According to our hypotheses, a less enduring IOR effect could allow deaf subjects to reorient their attention to recently explored locations after intervals at which hearing people still show a strong bias against those locations. The adaptive consequences of such differences are noteworthy. Deaf SLS experts have to continuously change their attentional focus between two stimulus sources very important for interpersonal communication, the speaker's face and hands, and long lasting IOR might prevent the processing of relevant information at those locations.

GENERAL DISCUSSION

The results of the present study suggest that several operations involved in orienting visual attention work differently in deaf than in hearing individuals. First, peripheral cues could increase alertness in deaf more than in hearing subjects (see also Colmenero et al., 1998), since the deaf subjects detected targets faster than the hearing subjects irrespective of SOA (Experiment 1). Second, the reduced costs in the invalid trials observed in deaf but not in hearing people (Experiment 1) can be attributed to a faster disengaging attention mechanism (see also Colmenero et al., 2000). Third, the results of Experiment 2 show that IOR is resolved earlier in deaf than in hearing people, preventing the former from losing relevant information in a complex environment where relevant signs for communication occur with a high frequency. All these results suggest that deaf people disengage attention faster and resolve IOR earlier than hearing people, fostering a more efficient exploration of their visual environment according to their communication demands.

Nonetheless, we envisage several caveats that might question the above contentions. The difference between deaf and hearing subjects might be due to the lack of catch trials in the present experiments, having the deaf group a stronger bias to anticipate responses to targets. However, we think that there are several main reasons why this anticipatory explanation can be ruled out. First, the percentage of responses shorter than 120 ms that were excluded from the data analyses was nearly equal in both groups of subjects. In addition, that cutoff for excluding anticipatory responses is on the range of that used in related studies (see Taylor & Klein, 2000). Second, deaf people were indeed faster than hearing people in Experiment 1, but slower, although not significantly so, in Experiment 2. Third, the anticipation hypothesis states that response is triggered by the cue onset so that SOA should have no effect on response speed. However, we found shorter RTs for longer than for shorter SOAs. Moreover, according to the anticipatory hypothesis neither cue validity nor IOR effects should be observed. Fourth, RTs in our experiments are similar to those obtained in other laboratories that used similar procedures (i.e., Taylor & Klein, 2000; Theeuwes & Godijn, 2002). Thus, it seems that the present results can be better accounted for in terms of attentional processes than as a mere anticipation strategy in the deaf group.

Another caveat concerns the scarce number of cue–target SOAs used in Experiment 2. The complete time course of IOR in deaf people wasn't at the core of the present study. The reduction of costs and the lack of benefits of the cue validity effect we have observed in Experiment 1 lead us to conclude that deaf people disengage attention faster than hearing people. Therefore, we suggest that spatial processing demands imposed by the signed language can be better achieved by having a short-lived IOR effect. In this vein, we cannot indicate the specific SOA at which the deaf's IOR effect disappears, but results of Experiment 2 firmly indicate that this happens rather early compared to hearing people.

A final question is whether the present results can be better accounted for in terms of an increased ability of deaf people to divide their attentional focus between two relevant locations, that of the cue and that of the target. However, in our experiments there was a single target, and the task did not require dividing attention between two target locations. Also, the division of attention appears to be precluded by abrupt onset of the target (Hahn & Kramer, 1998; Kramer & Hahn, 1995). Alternatively, however, it can be possible that deaf people are better distributing their attention across the visual field. Our results cannot discard this possibility, but it is necessary to note that the eccentricities we used (20° and 14° in Experiments 1 and 2, respectively) defined a visual field area (40° and 28°) too big as to be effectively attended at once. All these circumstances favour the idea that all subjects changed the location of attention to perform the task effectively.

In conclusion, our results suggest that the visual processing demands imposed by hearing impairment can lead to trained people in SLS to change the way their spatial attention mechanisms operate. Here we have demonstrated that SLS deaf experts can disengage their attention from a peripheral location faster than hearing people, and that IOR resolves earlier. These changes in spatial attention dynamics allow deaf people to explore more spatial locations than hearing individuals during a fixed amount of time

Further research is needed as to determine remaining important issues raised from these preliminary results as the time course of IOR in deaf individuals, the relationship between disengaging and IOR in hearing and deaf people, and the factors that produce a remarkable change in the way the basic mechanisms of visual attention work according to the demands imposed by the auditory impairment.

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