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INVESTIGATING THE CO-OCCURRENCE OF VISUAL AND AUDITORY NEGLECT IN A PATIENT WITH RIGHT HEMISPHERE STROKE: A CASE STUDY

By
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Investigating the Co-occurrence of Visual And Auditory Neglect in a Patient with Right Hemisphere Stroke: A Case Study

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To my father Antoine, my mother Ramona and my sister Ramona,

for giving me the opportunity to be who I am.

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Abstract

Unilateral spatial neglect (USN) has been observed in individuals suffering brain damage, specifically in the right hemisphere. USN is characterized by a failure, on the part of the patient, to orient towards, respond to, or report stimuli (visual, auditory or tactile...) presented in the hemispace contralateral to the hemisphere with the damage. Does USN involve modality-specific or supramodal mechanisms? In the present study the supramodality of USN is examined. Using updated versions of the Tachistoscopic Presentation (TP) and the Dichotic Listening (DL) tests, the co-occurrence of contralateral visual and contralateral auditory neglect is investigated. The purpose of the TP test is to compare the frequency of target identification in the left quadrants, center, and right quadrants of the screen. The purpose of the DL test is to compare frequency of correctly reported consonant-vowel syllables from the right and left ear during a non-forced, forced-right, and forced-left attentional condition. A case study of a 60-year-old male with a massive right hemisphere cerebrovascular accident is presented. A normal control participant was also tested. The patient's lesion involved the frontal, temporal and parietal lobes and the inferior parietal lobule. Neurological examination revealed left hemiparesis, left upper quadrant hemianopia and left hemianesthesia. The patient exhibited both left visual neglect and left auditory neglect. The results also showed that, compared to the control participant, the patient neglected, although less frequently, visual and auditory stimuli presented in the right hemispace. In addition, when the patient was interviewed for anosognosia, he showed unawareness of visual and auditory neglect, of hemianopia, and of the exact nature of his illness and its implications. On the other hand he was to some extent aware of his motor defect, i.e., hemiparesis. The results of the

follow up on the prognosis of visual neglect showed a clear amelioration of neglect in the left visual hemispace and especially in the right hemispace. The results were discussed within the attention-arousal model of Heilman and his coworkers. The findings supported a supramodal neglect syndrome and the hypoarousal model proposed by Heilman and his coworkers.

CHAPTER I

Introduction

The neglect syndrome is one of the disorders of attention caused by certain neurological diseases. In the absence of attention most human behavior becomes inefficient. Neglect generally follows hemisphere damage and influences the individuals' attention to parts of the space. An important characteristic of the human (use of) attention is its selectivity in what to pay attention to. According to Heilman, Valenstein and Watson (1992), the selectivity of attention to a stimulus is based on the stimulus attributes such as its direction in space or modality (visual, auditory, or tactile). The significance of a stimulus depends either on its novelty and/or on the needs of the organism. Moreover, the failure of an organism to notice significant stimuli when the defect cannot be attributed to an elementary sensory deficit is called sensory inattention.

Patients with hemisphere damage may exhibit sensory inattention to significant stimuli, with the inattention being to stimuli presented in the space contralateral to the damage. Patients showing neglect of the whole hemispace contralateral to their brain lesion are assumed to have hemispatial sensory neglect, or unilateral spatial neglect (USN). Therefore, the basic behavioral characteristic of unilateral spatial neglect is the failure to orient towards, respond to, or report stimuli (e.g., visual, auditory) presented in the contralesional hemispace (Heilman, 1979; Heilman, Bowers, Valenstein, & Watson, 1987; Heilman et al., 1992). In addition, USN occurs in the absence of lesions in the primary sensory areas or the sensory projection system, in the absence of motor deficits or of motor neglect (Heilman et al., 1987). A number of research findings (e.g., Soroker, Calamaro & Myslobodsky, 1995b; Vallar, Bottini, Rusconi & Sterzi, 1993) indicate that the deficient system continues to register sensory signals indexed by analyzing event-related potentials.

Neglect does not take exactly the same form in all patients. The common feature among the different forms is behavior that is asymmetric spatially, favoring the ipsilesional to the contralesional side of space (Walker, 1995). There are several behavioral subtypes of hemispatial neglect such as motor neglect, personal neglect, spatial and object-based neglect, and sensory neglect that can be demonstrated in more than one modality (visual, tactile, auditory) (Heilman et al., 1987; Walker, 1995). Although these subtypes often coexist, they can occur in isolation (Heilman et al., 1987).

There are various theoretical accounts with respect to the nature of the underlying mechanisms of USN. Some regard neglect as a unitary syndrome (supramodal hypothesis), others as mutually exclusive manifestations (unimodal hypothesis). The exact relationship between the different forms of neglect is yet unclear and awaits further research. It is known that visual neglect is indicative of poor prognosis in the recovery of stroke patients. Elucidating the issue of unimodality or supramodality might have some implications for the rehabilitation of stroke patients with USN. The interest of the present research is in the investigation of USN in a patient with right-hemisphere stroke within the context of a supramodal interpretation of observations. The supramodality of neglect can be verified by assessing the co-occurrence of more than one form of neglect: in the present study the co-occurrence of visual and auditory neglect.

Neglect in Different Modalities

In humans, the unilateral neglect syndrome seems to be more frequent and severe after lesions in the right hemisphere than after lesions in the left hemisphere (Mesulam, 1981). It manifests itself as left hemispace inattention. Heilman et al. (1987) described hemispace as

> A complex concept because it can be defined according to the visual half field, head hemispace, or trunk hemispace. With the eyes and head facing directly ahead, so that the midsagittal plane of all these structures is parallel, all three hemispatial fields are congruent. (p. 115)

Hemispace can be defined within either egocentric (body-referenced) or allocentric (object-referenced) coordinate systems (McCourt & Olfason, 1997). It follows that the definition of left depends on the frame of reference involved (Ladavas, 1993; as cited in Walker 1995). Within the egocentric frame of reference, left is defined with respect to the viewer's own body coordinates. Thus, left is the patient's left visual field with respect to retinal coordinates. It can be the left of the patient's body midline, when taking the patient's own body trunk as reference, or it can be the left of the head midline with respect to the patient's head (Walker, 1995).

Hemispatial inattention can affect different modalities. The present study focused on the syndromes of visual and auditory neglect. Although the detailed discussion of the other forms of neglect is beyond the scope of the current study, a brief description of these may help the reader better appreciate the complexity of USN.

One form of neglect is Akinesia or motor neglect. Akinesia is characterized by delay or inability to initiate goal-directed movements to the affected limb's space (ipsilesional) (Heilman et al., 1992; Stein & Volpe, 1983). This is illustrated by the patient's failure to respond to ipsilateral stimuli with the contralateral arm (Heilman et al., 1992). Some patients exhibit hemispatial or "Directional Hypokinesia" (Husain & Kennard, 1996), a difficulty in moving the head or eyes or a limb in order to explore the hemispace contralateral to a hemispheric lesion (Heilman, 1979; Heilman et al., 1987). In this case, the patient fails to respond to contralateral stimuli with the ipsilateral arm, which suggests inattention (Heilman et al., 1992). Usually, patients with visual neglect exhibit gaze paresis which is a partial or complete paralysis of contralateral gaze (Rubens, 1985). These disorders are not caused by primary deficit of the motor neurons related to these functions.

Tactile neglect is another form of neglect. Tactile or somatesthetic neglect reflects the inability of patients to detect unseen stimuli either when these are presented on their bodily surface (Vallar, Bottini, Sterzi, Passerini, & Rusconi, 1991) or when they are engaged in a searching task in extrapersonal space (Pellat, Carbonnel, Chanal, Charnallet, Nicoul, & Gaio, 1986; as cited in Beschin, Cazzani, Cubelli, Della Sala, & Spinazzola, 1996). Heilman et al. (1987) argued that tactile neglect is independent of hemispace variation because, for instance, a patient does not respond better to stimuli applied to the left hand when the hand is moved into right hemispace.

Another distinction is made between spatial and object-based forms of neglect. Spatial neglect is indicated by a tendency to omit stimuli located on the contralesional side of space. In these cases, space is defined in egocentric coordinates. Walker (1995) noted that in the spatial manifestations of neglect, patients would omit whole words when reading a text; and the omissions occur at one side of the page. On the other hand, object-based neglect is manifested by a tendency to omit the contralesional side, or parts of the contralesional side, of an individual object regardless of its spatial (ipsilateral or contralateral) position. In these cases neglect occurs in an object-referenced coordinate system (e.g., Young, Hellawell, & Welch, 1992; as cited in Walker, 1995). For example, Walker (1995) cited Ellis, Flude & Young (1987) and Young, Newcombe, & Ellis (1991) who found that when patients with neglect were shown words, they tended to omit the left sides of a word in normal orientation or when rotated by 180 degrees. This phenomenon is referred to as neglect dyslexia. For instance, the patient, when reading PEARL, reported 'earl' when the word was presented in normal orientation and 'pear' when the word was rotated by 180 degrees. This demonstrated that neglect was based on the stimulus (object-based) and may not be regarded as being word-centered (object-centered) since in both cases the patient neglected the left side of the word regardless of its position in the space. In fact, they omitted reading the P when the word PEARL was presented in normal orientation while they omitted the L when the word was rotated by 180 degrees, rather than omitting the P irrespective of the presentation condition. Furthermore, Walker specifies that in most tasks in which neglect is manifested, it is important to elucidate the frame of reference. It is known that neglect can occur in terms of more than one of these frames of reference, and the degree of neglect can therefore be influenced by changes in the patient's viewing position.

Yet another form of neglect that some patients may exhibit is personal neglect or asomatognosia. Patients with asomatognosia fail to recognize their own limbs that are contralateral to the lesion, complaining, for instance, that someone else's arm or leg is in bed with them (Heilman et al., 1987; Heilman et al., 1992; Stein & Volpe, 1983).

Patients with neglect may also fail to be aware of their disorder (anosognosia). This is an important feature that must be taken into account during the assessment of neglect. Anosognosia is a factor that often hinders rehabilitation and recovery of right hemisphere stroke patients (Karla, Perez, Gupta, & Wittink, 1997). Anosognosia was defined in early studies (Von Monakow, 1885; as cited in Bisiach, Vallar, Perani, Papagno, & Berti, 1986) as the unawareness of disorders following brain lesion. Unawareness was defined as a discrepancy between the subject's description of abilities and objective measurements of those abilities assessed by neuropsychological and neurological evaluations.

Some of the later studies used Babinski's definition describing anosognosia as the patients' denial of either weakness or of syndromes such as neglect, left hemiplegia, left hemianopia, Wernicke's aphasia, or dyslexia (Bisiach et al., 1986; Cutting, 1978; Heilman et al., 1992). Anosognosia can range from indifference about the illness (anosodiaphoria) to an explicit verbal denial (Bisiach et al., 1986). For example, hemiplegic patients would deny being brought to hospital because of hemiplegia, even after being confronted with their impairment, whereas patients with anosodiaphoria (Cutting, 1978; Heilman et al., 1992) or indifference would lack genuine concern about their illness. In the present study, the term anosognosia is used to refer to failure on the part of the patient to acknowledge acquired motor, visual and cognitive deficits in response to explicit questioning, the most commonly used operational definition in the literature on USN (e.g., Anderson and Tranel, 1989).

Two controversial hypotheses have been suggested to explain anosognosia. First, in most of the theories (e.g., Head & Holmes, 1911; as cited in Heilman et al., 1992) anosognosia is explained as due to a defect in feedback mechanisms. However, according to Heilman et al. (1992), this hypothesis cannot explain denial of hemiplegia when the arm is brought into an intact visual field. These authors proposed the intentional theory of denial suggesting that anosognosia could be related to a so-called "feedforward" mechanism. Within this framework anosognosia is explained as impairment in the feeding of information about motor expectations to comparator systems. This impairment of the intentional system leads to an inability to activate motor neurons, and the comparator system cannot detect the mismatches between the intention to move the limb (expectation) and the inability to move it (performance). In turn this leads to no awareness of deficit (Heilman et al., 1992). However, more light needs to be shed on the nature of anosognosia.

Visual Neglect

As mentioned earlier, visual neglect involves the absence of awareness of visual stimuli in the visual field contralateral to the lesion (Heilman et al., 1992; Springer & Deutsch, 1993). The spatial manifestations of neglect can be observed in patients' everyday behavior. They may ignore people, objects or events to their left (Husain, Shapiro, Martin, & Kennard, 1997). For example, some patients may fail to eat from the left side of their plate, others may shave, groom, and dress only one side of the body; while still some others may omit to read part of a word or a sentence (Mesulam, 1981). Left-sided spatial neglect can also lead patients to deviate to the right of the center when walking (Robertson et al., 1994; as cited in Walker, 1995) or when reaching for an object

(Chieffi, Gentilucci, Allport, Sasso, & Rizzolatti, 1993, & Goodale, Milner, & Jakobson 1990; as cited in Walker, 1995). In severe cases, patients may behave as if that half of the universe had abruptly ceased to exist (Mesulam, 1981). As mentioned earlier, unilateral visual neglect in humans appears to be most severe and most frequent following lesions to the right cerebral hemisphere (Heilman, 1979). According to Husain et al. (1997), visual neglect affects over 70% of stroke patients. Usually neglect improves in the first few months following a stroke in the majority of the patients (Storrie-Baker, Segalowitz, Black, McLean, & Sullivan, 1997). However, the presence of neglect following a stroke is indicative of a poor prognosis for recovery of activities, which are daily functions (Azouvi et al., 1996).

This phenomenon of visual neglect has been variously termed hemispatial neglect, visuospatial agnosia, visuospatial neglect, and unilateral spatial neglect. In the present study I use the term visual neglect when specifically referring to neglect in the visual modality.

Severe visual neglect is difficult to distinguish from hemianopia without knowing the site of the brain lesion. Hemianopia is due to damage in primary sensory areas. Patients with hemianopia, unlike patients with visual inattention, may be able to detect a stimulus in the contralateral side if their attention is directed to that side (Heilman et al., 1987). During the acute phase of neglect, many patients may also exhibit directional gaze bias and corresponding head turning. This may significantly contribute to visual neglect (Rubens, 1985).

Auditory Neglect

Until recently, USN was illustrated as the syndrome of visual neglect. As a result very little effort had been made to investigate auditory inattention (Soroker et al., 1995b). Early findings concerning auditory neglect emerged during Word War II, when in a number of cases, impairment in spatial hearing was found not to be associated with acuity loss (Alexeenko, Blinkov, & Gershuni, 1949; as cited in Soroker et al., 1995b). This implied a deficient auditory field or hemispace function rather than an ear dysfunction (Heilman & Valenstein, 1972a).

Generally, unilateral hearing loss does not occur after a unilateral lesion in the central nervous system because verbal information can still get around via the direct and/or subordinate ipsilateral pathway to the undamaged hemisphere (Denny-Brown, Meyer, & Horenstein, 1952). Accordingly, patients without hearing loss who neglect or orient incorrectly to unilateral auditory stimuli often have unilateral auditory neglect (Heilman & Valenstein, 1972a; Heilman et al., 1992).

Furthermore, these patients, if right hemisphere damaged, do show errors of localization and lateralization of auditory stimuli, shifting them towards the right side (Bisiach, Cornacchia, Sterzi, & Vallar, 1984). For example, some patients respond by turning their head and eyes to the right (ipsilateral side) when being addressed or spoken to from the neglected left side (De Renzi, Gentilini, & Barbieri, 1989; Heilman & Valenstein, 1972a). Denny-Brown et al., (1952) studied a case where the patient always reported the direction of the sound coming from the right even though sounds were coming from both directions. These studies emphasized that patients with auditory neglect exhibited a defect especially under simultaneous binaural stimulation and in test situations different from everyday life activities (De Renzi et al., 1989; Heilman & Valenstein, 1972a; Heilman et al., 1992).

Extinction

Related to USN is the phenomenon of extinction. It is the failure to respond to visual, auditory, or tactile stimuli in the contralateral field or limb after bilateral simultaneous stimulation (BSS) (Stein & Volpe, 1983). Patients who exhibit extinction to BSS do respond to stimuli in isolation. Hence, when testing for extinction, tactile stimuli are applied to the left and right halves of the body, and visual or auditory stimuli are presented in both the left and the right hemispace (Pollmann, 1996). Extinction may occur either in one modality or multimodally (Heilman et al., 1992).

Although patients with acute neglect recover and become able to detect a contralateral stimulus, extinction is frequently observed as a residual symptom (Heilman et al., 1992; Pollmann, 1996). Similarly, in the cases of less severe neglect, neglect can be elicited in the form of unilateral extinction during BSS for in these cases the observation of spontaneous responses to unilateral stimulation may reveal no abnormality (Mesulam, 1981). Extinction, like neglect, is considered to be a form of spatial attention deficit (Farah, Wong, Monheit, & Marrow, 1989). Furthermore, Heilman (1979), Heilman et al. (1987), Heilman et al. (1992), Mesulam (1981), and other authors (Stein & Volpe, 1983) consider extinction as representing a part or component of the neglect syndrome.

Conversely, and based on their findings about auditory neglect, De Renzi, Gentilini, and Pattacini (1984) suggested that extinction, unlike neglect, is more likely to have a sensory than an attentional basis. Auditory extinction is the failure to perceive a stimulus in the contralateral ear when it is simultaneously delivered to the ispilateral ear. When assessing patients with unilateral stroke for auditory extinction, these authors found that half of their patients had auditory extinction. But contrary to the observations with visual neglect, auditory extinction lacked asymmetry, that is, did not correlate significantly with right hemisphere damage (RHD). Moreover, for some of the patients with RHD who exhibited a long lasting pattern of extinction, their injury was located in areas that interrupted the central auditory pathways traveling from the medial geniculate body to the temporal cortex (De Renzi et al., 1989). Also, in a subsequent study, when investigating the relation of auditory neglect to auditory extinction, De Renzi et al. (1989) found that there were seven out of thirty right hemisphere damaged patients who showed extinction, but not neglect, and two patients who exhibited the opposite pattern. All these findings challenge the view that extinction is a minor form of neglect (De Renzi et al., 1989).

Assessment of Visual Neglect

In testing for inattention, novel stimuli are presented, and patients are assessed on appropriate orienting to the stimulus. Clinical bedside testing is typically used when testing for auditory and/or visual neglect. It consists of confrontational techniques such as making sounds by rubbing or snapping the fingers or having the patients detect the movement of fingers (Heilman et al., 1987; Heilman et al., 1992).

In addition to bedside testing and close observation of patients when they are walking or handling objects, visual neglect can be assessed using a wide range of neuropsychological methods. A class of these methods, the "spatial operation" tasks (Heilman et al., 1987), is used in assessing visual neglect. One category of these tasks is the Marking Tasks for testing visual inattention. The most commonly used type of marking task is the Cancellation Task. There are many forms of Cancellation Tasks. The simplest form (Albert 1973) consists of asking the patient to cross out all of the lines that are randomly distributed on a page (Heilman et al., 1987; Lezak, 1995; Walker, 1995). Patients with visual neglect fail to cancel lines on the contralesional side of the page. Although visual neglect is most frequently investigated in the horizontal plane, alterations are also observed in the responses of patients with RHD, who more often omit crossing out lines on the left inferior quadrant of the page than on the left superior quadrant (Morris, Mickel, Brooks, Swavely & Heilman, 1986).

A second commonly used category of spatial operation tasks is the Line Bisection Task. In the Line Bisection Task, the patient is asked to bisect (by placing an X in the center) a horizontal line that is already drawn or that he/she is asked to copy. Patients with RHD with visual neglect, for example, deviate toward the right of the actual center of these lines (Heilman et al., 1987). Moreover, in a number of studies (e.g., Halligan & Marshall, 1994) patients bisected vertical lines above their actual center. This reflects that neglect is also manifested in a vertical or inferior altitudinal dimension, either at the hemispace or plane level as illustrated in the example of the Cancellation Task of Morris et al. (1987) above, or at an object-based level as illustrated in the examples of Heilman et al. and Halligan and Marshall. Walker (1995) mentioned that various other clinical tests are also used to assess the presence and severity of neglect. These include picture description, writing, drawing and copying, and reading tasks. The latter identifies the presence of spatial neglect when patients distort or omit words located on the contralateral side of the page.

It should be noted that more than one of the neuropsychological tests mentioned earlier failed to detect neglect in a number of samples of patients with visual neglect

(Lezak, 1995). Also, a single trial might sometimes not be enough to reveal neglect. This suggests that it would be better not to rely on one trial or on one type of test while examining patients with visual neglect. Different neuropsychological tests have been shown to have different sensitivity levels (Azouvi et al., 1996). Azouvi et al. (1996) suggested this differential sensitivity to be related to the heterogeneity of the neglect syndrome that is manifested differently in different patients. A further problem with the neuropsychological tests is that a number of factors might increase the neglect phenomenon and hence increase the apparent sensitivity of a test (Lezak, 1995). One such factor can be the meaninglessness and discontinuity of a stimulus. Another factor can be the presence of a distracting stimulus inside the space ipsilateral to the lesion. Moreover, when given a long test such as a series of cancellation tasks, patients are easily fatigued and, hence, make more errors. It should also be noted that rating and performance for such tasks are rarely standardized (Azouvi et al., 1996).

A standardized test battery is the Behavioral Inattention Test (BIT) by Wilson, Cockburn, and Halligan (1987). It is used to assess the severity of unilateral visual inattention. A number of studies (Halligan & Marshall, 1994; Husain & Kennard, 1996; Soroker, Calamaro, Glicksohn, & Myslobodsky, 1997; Soroker, Calamaro, & Myslobodsky, 1995a; Soroker et al., 1995b) I reviewed while investigating hemispatial neglect, used the BIT. The BIT was developed to provide an objective behavioral examination of everyday skills (naturalistic) related to neglect, whether right or left. The BIT consists of two sections, the "conventional subtests" and the " behavioral subtests". The conventional subtests consist of: line crossing, star cancellation, figure and shape copying, line bisection, representational drawing, and letter cancellation task. The behavioral subtests consist of: picture scanning, menu reading, article reading, address and sentence copying, telephone dialing, telling and setting the time, coin sorting, and map navigation.

One problem with the Line Bisection Task is that there is a possibility for patients to visually scan the working space. It is known that the direction of visual scanning affects bisection performance. In addition, the variability of the results in some of the prior studies using pencil-and-paper Line Bisection Tasks may be accounted for by the uncontrolled systematic scanning which permitted virtually unlimited inspection of the stimulus (McCourt & Olfason, 1997). Thus, a more sophisticated technique must be used to control the visual scanning variable. Such control of visual scanning may be accomplished by neuropsychological assessment through the use of Tachistoscopic Presentation (T-scope). Tachistoscopic Presentation is a sort of detection task. In a detection task patients are warned beforehand that a stimulus will be presented and are instructed to report the stimulus when or where they see or hear it. When using visual stimuli in order to dissociate visual field from body and head hemispatial neglect, it is best to use detection tasks (Heilman et al., 1987).

Tachistoscopic[1] Presentation addresses this confounding problem of visual scanning by limiting the presentation of stimuli on the screen to a brief duration. The displays are

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[1] Tachistoscope: An experimental apparatus for presenting visual information very briefly to the right or left visual field; sometimes called a T-scope. (Magill,1996; p.1612) The patient sits in front of a screen and he/she is required to fixate a central point, while visual stimulation is presented to either visual field. The device allows the investigator to control precisely the duration for which a picture or symbol pattern is presented on a screen. (Springer & Deutsch, 1993; p.34)

kept for about 150 or 200 ms in order to eliminate the effect of eye movements[2] while the target stimuli are still on the screen. Also, to ensure that the patient will not move his/her head or eyes, the patient is instructed to keep his eyes on a fixed point which is located in the middle of the screen. This procedure is also necessary for the lateralization of visual information. Hemispheric asymmetries in information processing are also investigated by T-scope or divided visual fields. The Tachistoscopic Presentation is a useful way of eliminating the contribution of eye movements in studies of object-based neglect (Walker, 1995). The forced-choice psychophysical procedure used in tachistoscopical presentation constitutes another advantage of this technique because it reduces the motor component of the response found in the more common methods of adjustment such as the Line Bisection Task. The spatial operation tasks mentioned above are complex. Failure on such tasks may be related to several factors: neglect may be due to hemispatial inattention, to directional or hemispatial akinesia, or to an exploratory defect. Defect in exploratory behavior might be due to a defect in either of its component systems: the motor-intentional and the sensory-attentional systems (Heilman et al., 1987). Hence, Tachistoscopic Presentation helps in isolating the perceptual-cognitive components of neglect from the motor component (McCourt & Olfason, 1997).

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[2] The rapid eye movements that occur when gaze is shifted from one point to another are known as saccadic eye movements or saccades. Although, once started, saccades are extremely rapid, they take about 200 milliseconds to initiate with the eye at rest, if a stimulus is presented for less than 200 milliseconds, then the stimulus is no longer present by the time an eye movement can occur.(Springer & Deutsch, 1993; p.34)

Because of the aforementioned advantages of the Tachistoscopic Presentation in the assessment of visual neglect, it was chosen as the method to be used in the present study.

Assessment of Auditory Neglect

Bedside assessment of auditory neglect starts by presenting the patient with stimuli separately to each ear or simultaneously to both ears, randomly varying these presentations to the right, left, or both ears. Patients who fail to respond to unilateral auditory stimuli most often have unilateral auditory neglect. However, according to Heilman et al. (1987), even if a patient is able to identify unilateral stimuli, but consistently misses one side with bilateral simultaneous stimulation, he is also considered to have auditory neglect.

However, the difficulty of showing neglect in the auditory modality using classical neurological bedside examination is probably due to the physical characteristics of acoustic stimuli and the arrangement of the neural apparatus transmitting them to the cortical centers. Although the contralateral auditory pathways have greater efficiency, the sound waves emitted by an acoustic source located in either sides of the space reach both ears, and are thence sent to both temporal cortices (De Renzi et al., 1989) . De Renzi et al. (1989) stated :

> It follows that, when the right hemisphere is damaged, the left hemisphere remains able to perceive and attend to a sound coming from the left side, due to its connections with both ears, ... It would appear that a prerequisite for bringing out

> auditory neglect, if it indeed exists, is to confine the acoustic stimulation to the ear contralateral to lesion. (pp.613-614)

A convenient method would be to present subjects with single pairs of dichotic stimuli. For patients with no acuity loss, a sound coming from one hemispace is heard by both ears. The fact that the patients are unable to report the sound, is indicative of inattention. So confining the source of sound to the contralateral ear prevents it from propagating through space to reach the ipsilateral ear. This eliminates localization cues of stimulus intensity difference and time of arrival to ear difference. Hence, it would be easier for the investigator to identify exactly the hemispace from which the sound has been ignored or neglected. In dichotic testing, the auditory recognition capacity of each ear is tested separately but simultaneously (De Renzi et al., 1989).

The Dichotic Listening (DL) test is a sort of detection task. It consists of simultaneous presentation of competing sets of auditory stimuli, such as Consonant-Vowel pairs or digits, to both ears through headphones by a dual sound track system (Kimura, 1967). The procedure consists of three sections. In one-third of the trials the subject is instructed to freely attend and report input from either ears. In the other two sections the subject is asked to selectively attend to and report the left ear input in one-third of the trials, and the right ear input in another third (Hugdahl, & Anderson, 1986).

The Dichotic Listening task involves the abilities to understand and to produce speech. Accordingly, it is a frequently used technique for the study of language lateralization. In addition, it has been postulated that Dichotic Listening taps mechanisms of brain asymmetry (Kimura, 1967; Springer, & Deutsch, 1993) , so it is commonly used in investigating phenomena linked with laterality research such as dyslexia and split-brain studies. Consequently, Dichotic Listening (DL) can be considered as the method of choice in the process of studying auditory neglect. In addition, Dichotic Listening is considered to assess different attentional functions like focused and divided attentional functions. It is considered to be the auditory counterpart to the visual Tachistoscopic assessment. Since we are dealing with stroke, hemianopia and heminegleet, both methods are favorable because they allow lateralization.

Lesions Inducing USN

CT studies have demonstrated that areas within the right hemisphere and some subcortical areas of the parietal lobe, especially the inferior parietal lobule, are most frequently associated with severe neglect (Heilman et al., 1992; Mesulam, 1981; Storrie-Baker et al., 1997; Vallar & Perani, 1987). Lesions of the medial -frontal, especially involving the cingulate gyrus (Heilman & Valenstein, 1972b) and dorsolatreral frontal lobe (Damasio, Damasio, & Chui, 1980; Heilman & Valenstein, 1972b) and of subcortical areas such as the basal ganglia (Damasio, Damasio, & Chui, 1980; Vallar & Perani, 1987) the thalamus (Vallar & Perani, 1987), and the mesensephalic activating system (Watson, Heilman, Miller, & King, 1974) have also been reported to be associated with neglect.

Husein and Kennard (1996) reported that stroke and severe neglect are associated most commonly with lesion in the region of overlap between the frontal and parietal lobe. This overlap region appears to include the inferior parietal lobule and the inferior frontal gyrus (Vallar & Perani, 1987).

Furthermore, Husein and Kennard (1996) studied five patients with left visual neglect following focal infarction of the right frontal lobe. The very small area of lesion overlap, among four patients, was found to be part of the Brodmann's area 44 (the dorsal aspect of the inferior frontal gyrus) and the immediate underlying white matter. In humans, this region is considered to be part of the premotor cortex, dorsal to which is the frontal eye field (Paus, 1996). Husein and Kennard suggested that area 44 in the right hemisphere may play an important role in directing attention in visual space or in planning movements to search in the contralateral space. They further noted that, in the right hemisphere, this Brodman's area is part of the homologue of Broca's area that is situated in the left hemisphere and which plays a role in speech production.

The issue of whether different locations of lesion lead to different neglect syndromes has been investigated. Mesulam (1981) has reported that the frontal lobe lesions were found in patients with directional hypokinesia while sensory neglect was found to be more associated with parietal lobe lesions. However, Bisiach, Geminiani, Berti, and Rusconi (1990), reported that motor neglect has been common in patients with lesions in both the frontal and parietal lobes. Valenstein and Heilman (1981) have presented evidence that dorsolateral frontal lesions emphasize the output disorder (of "intention"). But in its full elaboration, with anosognosia, denial and self-referential behavior, neglect requires a posterior parieto-temporal lesion (Kinsbourne, 1987). Another example is the study by Stein and Volpe (1983) who found that their three patients with subcortical right frontal lobe infarction exhibited the classical "parietal" neglect syndrome. A classical parietal neglect syndrome is mainly characterized by defective spatial perception such as defects in orienting and attending to sensory events. In the study, CT scans showed no abnormality in the parietal lobe of the lesioned hemisphere. According to Stein and Volpe:

> Our data support the view that for polymodal cortical association areas such as the parietal lobe, which connect a variety of distant cerebral areas including the frontal lobe and basal ganglia, damage in a part of the network may be associated with different aspects of the neglect syndrome. (p. 797)

Finally, Mesulam (1981) stated that this frontal-parietal or motor- sensory divergence is unlikely to be completely dichotomous.

From another perspective, Mesulam (1981) suggested a cortical network for directed attention and unilateral neglect. Based on studies on animals and humans, his proposal was of a network that includes certain structures of the brain which, when unilaterally damaged, can generate different clinical types of unilateral neglect. This is due to the uniqueness of their functions and anatomical connectivity. However, a lesion that comprises all the components results in profound deficits that exceed the mass effect of a larger lesion in one of these components. The network includes a posterior parietal component, a limbic component, a frontal component, and a reticular component. At least three of these components complement and interact with each other for the process of extrapersonal representations: a sensory representation in the posterior parietal cortex, a scheme for distributing exploratory movements in the frontal cortex, and a motivational map in the cingulate cortex.

Furthermore, severe unilateral neglect in humans is mostly attributed to the parietal lobe (Mesulam, 1981). The inferior parietal lobule is responsible of providing an internal sensory map for representing external space. As an illustration for the role of the parietal lobe Mesulam (1981) cited the results of Bisiach, Luzzati, and Perani (1979), indicating that the patients were less accurate in detecting differences on the left side of the objects, irrespective of whether the objects moved leftward or rightward under a slit. The fact that patients showed neglect when the constituent sensory information had originated in the non-neglected parts of the external world indicates that neglect can be a result of neglect of the inner representation rather than neglect of actual events in the extrapersonal space (Mesulam, 1981). Though an object is presented in the right external hemispace, there is still a distortion in the representation of the left portion of that object. This indicates a defect in the process of internal representation of an object in space.

Moreover, Mesulam states that the limbic component in the cingulate gyrus regulates the spatial distribution of motivational valence. Consequently, a lesion in this area can generate a loss in the perception of the biological importance of events in the contralateral space. This loss would impair the expectancy distribution for potential events and the attribution of motivational relevance to actual events in the hemispace contralateral to the lesion. The frontal lobe component coordinates the motor programs for exploring, scanning, reaching, searching, or manipulating objects in the contralateral hemispace. Patients with frontal neglect would therefore be expected to show unilateral neglect in tasks that require systematic and sequential scanning of the external space such as copying figures, route finding, letter cancellation, and even reading. In addition, the reticular component provides the underlying level of arousal and vigilance. Thus, focal mesencephalic infarcts that interfere with the reticular formation and its ascending connections result in severe disturbances of vigilance and arousal (Mesulam, 1981).

Sill within the framework of Mesulam's network, a hemispheric lesion rarely affects only one specific function because brain functions are interconnected to each other and operate interdependently in the coordination of any one complex function. According to Mesulam:

> In naturally occurring lesions that come to clinical attention, damage is rarely confined to one of the four components .... The same patient may show marked extinction, a distorted inner representation of external space, failure to scan the contralateral hemispace, devaluation of its biological significance, and even diminution of overall arousal and vigilance .... The deficit is not one of seeing, hearing, feeling, or moving but one of looking, listening, touching, and exploring. The neglect encompasses extrapersonal space, body surface, and even intrapsychic representations. (p. 318)

In addition, lesions, which interrupt the interconnections among these network components, may disrupt the effective coordination of directed attention through a mechanism of disconnection.

Theories of Pathophysiology

Before I outline any of the theories of pathophysiology, note that each hemisphere is responsible for receiving stimuli from the contralateral visual field and for controlling the contralateral limbs. Heilman (1979) and Heilman et al. (1992) proposed that, independent of which limb is used or of the hemisphere where the stimulus is being presented, each hemisphere is responsible for *attending* and *intending* in the contralateral hemispace.

Therefore, a lesion in one hemisphere is mostly associated with the disturbance of the brain mechanisms that mediate different classes of behavior in the hemispace contralateral to the patient's lesion as observed in neglect (Kinsbourne, 1987; Mesulam, 1981).

Several neuropsychological mechanisms are claimed to account for unilateral neglect: (a) hemispatial or directional hypokinesia for movements towards the contralesional space (Heilman et al., 1992); (b) memory or representational distortion of a contralateral sector of a stimulus (Bisiach et al., 1984; Vallar, Bottini, Rusconi, & Sterzi, 1993); (c) spatial attention: directional attention bias (Kinsbourne, 1987), limited disengagement of attention from ipsilesional cues (Bisiach, Rusconi, Peretti, & Vallar, 1994; Posner, Walker, Friedrich & Rafal, 1984), and Hypoarousal (Heilman et al., 1987; Heilman et al., 1992).

An example of findings where neglect could be accounted for by hemispatial or directional hypokinesia of eye, head, or limb movement is a study by De Renzi, Faglioni, and Scotti (1970) (as cited in Heilman et al., 1987; in Heilman et al., 1992; and in Mesulam, 1981). In the study, blindfolded patients with neglect failed to explore the contralateral side of space when using the ipsilateral hand. This might have resulted from a motor bias ("intentional defect") toward ipsilateral hemispace (Heilman et al., 1992) .

Bisiach and Luzzatti (1978) (as cited in Heilman et al., 1992) studied the neuropsychological mechanisms of the distortion of inner representation in patients with visual neglect. In the study patients with RHD had to describe landmarks (the main square of Milan) from memory using various vantage points. Regardless of their (imagined) vantage points, patients failed to process accurately the left side of visual images indicating a representational disorder in reconstructing the left half of the images. Bisiach and Luzzatti suggested a representational map hypothesis whereby the visual image recollected

by the mind may be split between the two hemispheres. Bisiash et al. (1984) cited an earlier study of theirs (Bisiach, Capitani, Luzzatti, & Perani, 1981) where neglect patients presented with pictures failed to describe the left half of recollected visual images; these results have been interpreted in terms of impairment of the internal representation of egocentric space.

As for the spatial inattention account of neglect, a number of theories have been proposed. The first theory that I will discuss within this framework was proposed by Kinsbourne (1987), who explains neglect as a defect in the orientation response. His theory postulates a mutual-inhibition model (Storrie-Baker, 1997), which implies that both hemispheres compete with each other for controlling lateral orientation and action (Kinsbourne, 1987). Accordingly, a lesion in one hemisphere leads to an imbalance in this opponent system that controls brainstem output mechanisms (Storrie-Baker, 1997). Damage in the right hemisphere, which releases the left hemisphere from inhibition, decreases inhibition of the left hemisphere and hence increases its activation. This results in increased attention to the contralateral right direction (Kinsbourne, 1987).

In other words, the orienting bias of the lesioned right hemisphere becomes weaker than that of its opponent left hemisphere, resulting in a gradient of attention from left (low) to right (high) (Pollmann, 1996). This concept of gradient of attention opposes the left-right hemispatial dichotomy. It follows that neglect is a directional rather than a hemispace phenomenon. Hence, according to Kinsbourne's mutual-inhibition model, unilateral neglect results from an attentional bias rather than from an attentional deficit. This attentional bias is manifested by: (a) an orienting tendency towards the stimulus presented ipsilaterally to the lesion, (b) a rightward gaze bias and turning tendency, (c) exaggerated attention to the extreme right of a display, irrespective of its absolute location, as well as impaired attention to the left (Kinsbourne, 1987).

Kinsbourne (1987) further suggests that, in normals, the rightward-orienting tendency, or left hemisphere-orienting bias, is more powerful than the leftward-orienting tendency as revealed by minor behavioral asymmetries. This can be noticed in instances of left brain activation such as verbal communication that is accompanied by rightward turning. Hence, behavioral asymmetries arise from imbalance in the level of hemispheric activation. Accordingly, Kinsbourne (1987) explained the preponderance of left over right neglect syndromes. When the rightward-orienting tendency of the left hemisphere is disinhibited due to right hemisphere damage, it generates more extreme lateral-orienting tendencies than the disinhibited leftward-directed tendency. In other words, according to this behavioral asymmetry, the left hemisphere is dominantly activated. Neglect is then a result of inhibited orienting tendency toward the contralateral left hemispace, in addition to the left hemisphere orientation bias being more powerful than the right hemisphere orientation bias. It follows that the severity of the neglect symptoms would be proportional to the strength of the orienting tendency of each hemisphere.

Within this Kinsbournian framework, the results of the Line Bisection Task can be explained as follows. Patients with visual neglect have their attention directed to the stimulus ipsilateral to the lesion. Accordingly, patients with RHD and with hemispatial neglect would overestimate the size of the ipsilateral (right) side of the line (to be larger than it really is). Hence these patients would judge the phenomenological center of the lines as more deviated to the right (ipsilesional) of the actual center of these lines (Heilman et al., 1987).

Kinsbourne (1987) further suggests that neglect occurs in selective rather than absolute spatial location; that is, neglect is a direction-specific spatial impairment (Pollmann, 1996). Attention is not directed to the right hemispace but rather to the right part of any space, whether it is a whole visual space or a single hemispace (left or right). Similarly, Posner et al. (1984) agree with Kinsbourne and explain neglect as a difficulty to disengage attention from its current focus on an ipsilateral stimulus when shifting attention to the contralesional direction is required. Notably, patients with neglect are strikingly slow in shifting attention contralesionally, even when they initiate the shift within the intact visual half field and direct it to a more centrally located target that is still within the same intact visual half field. Posner, Inhoff, Freidrich & Cohen (1987) suggest that it is the parietal lobe that allows disengagement of attention from its current location, thereby allowing other brain centers to move attention to a different location and re-engage that attention there.

A more recent finding related to the attentional theory of USN concerns the attentional blink (Husain et al., 1997). Attentional blink is a measure of human ability to allocate attention over time (temporal attention). The human's ability to detect a second visual object after the appearance of a preceding one is impaired if the second stimulus occurs within 400 ms after the first one. Using a protocol for assessing the attentional blink, Husain et al. (1997) examined temporal dynamics of visual attention in USN patients with right parietal, frontal or basal ganglia strokes. Patients with visual neglect had an abnormally severe and protracted attentional blink. The ability of these patients to detect a subsequent letter after having identified a previously displayed one was significantly diminished compared to normals. They needed a length of time that was three times as long as for normals, even if both stimuli were presented at the same location. According to Husain et al., their findings demonstrate "for the first time" that visual neglect is a disorder of directing attention in time, as well as space. They also suggest that neglect has two components: "First, there is a spatial bias to direct attention towards stimulation processed by the undamaged cerebral hemisphere, and second, there is a deficit in temporal processing, regardless of where attention is directed." (p. 156)

The final theory I discuss here, also attributing spatial neglect to attentional defect, was proposed by Heilman and his colleagues. Heilman (1979), Heilman et al. (1987), and Heilman et al. (1992) agree with Kinsbourne that neglect is a defect in orientation response but disagree with the mutual-inhibition model. They propose instead a hypoarousal model. They suggest that unilateral lesions responsible for contralateral neglect induce a unilateral hemispheric hypoarousal, with an ensuing ipsilateral bias in the orienting response, and an impaired ability to shift attention to the contralesional direction. In addition, they proposed that the right hemisphere is dominant for mediating attention-arousal responses, so unilateral inattention is more likely to result from right-hemisphere damage than from left-hemisphere damage (Heilman, 1979; Storrie-Baker, 1997). The postulation that the right hemisphere is dominant for mediating attention-arousal responses is supported by observations that evoked responses to visual and somatosensory stimuli are generally of greater amplitude in the right hemisphere (Schenkenberg, Dustman, & Beck, 1971; as cited in Mesulam, 1981). Heilman (1979), Heilman et al. (1987) and Heilman et al. (1992) suggest that sensory neglect is a unilateral defect in attention-arousal induced by dysfunction in a corticolimbic-reticular loop or network, similar to the network proposed by Mesulam (1981). The dysfunction in the corticolimbic-reticular loop might occur following a lesion in one or more of the areas composing this network. These include cortical areas such as the frontal, parietal and temporal lobes; areas of the limbic system such as the cingulate gyrus; and subcortical areas such as the thalamus, and mesencephalic reticular formation (MRF) that mediates orientation responses (Heilman et al., 1987). According to Heilman and his colleagues, these subcortical areas have been shown to be implicated in arousal and attention. Evidence comes from electroencephalogram (EEG)[3] desynchronization following stimulation of the MRF.

Based on these findings Heilman and coworkers suggested a set of mechanisms for the pathophysiology of inattention, where the mesencephalic reticular activating system (MRAS) and the inferior parietal lobe play an important role. The MRAS influences the cortical processing and the transmission of sensory stimulation to the sensory cortex. The MRAS connects to the nucleus reticularis thalami (NR), a thin reticular nucleus enveloping the thalamus. In turn, the NR projects to the thalamic relay nuclei that relay information to the cortex (Heilman et al., 1992). NR appears to inhibit the relay of sensory information to the cortex (Schiebel & Schiebel, 1966; as cited in Heilman et al., 1992) by acting on the thalamic relay nuclei. Furthermore, rapid MRAS stimulation or

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[3] EEG: the traces obtained when the electrical activity of the brain is recorded by means of electrodes placed upon the intact scalp (Churchill's Medical Dictionary, 1989). EEG can be used as a physiologic measure of arousal (Moruzzi & Magoun, 1949; as cited in Heilman et al., 1987).

behavioral arousal indirectly enhances thalamic sensory transmission to the cerebral cortex by inhibiting the nucleus reticularis through their interconnections (Heilman et al., 1992). Also, the thalamic relay nuclei become more inhibited by the NR activation; hence, sensory stimuli are inhibited from reaching the cortex. This happens following a lesion in MRAS, which would interfere with the process of inhibition of the NR. The authors also postulated that the MRAS projects diffusely to the cortex by multisynaptic pathways (Heilman et al., 1992) . This may induce a general state of arousal.

In sum, a unilateral lesion in the MRAS will lead to unilateral inattention either due to a decreased thalamic transmission of sensory input to the cortex or because the mesencephalic reticular formation does not arouse or prepare the cortex for sensory processing, or both (Heilman et al. 1992).

Moreover, sensory information is transmitted through projections from the primary sensory cortex (for audition, vision, ...) to their reciprocal unimodal association cortex. On the one hand, specific parts of the reticular nucleus (NR) of the thalamus project to the unimodal association cortex, and thereby gates sensory input in one modality. Hence, lesions of the unimodal association cortex may induce unimodal perceptual loss or inability to synthesize contralateral unimodal sensory input (Heilman et al., 1992). On the other hand, Unimodal association areas converge on polymodal association areas such as the prefrontal cortex, the superior temporal sulcus, and the inferior parietal lobule. These areas have strong reciprocal connections as well as connections with the brainstem reticular formation (Heilman, 1979), and may subserve cross-modal associations (Heilman et al., 1992).

The polymodal association cortex, in addition to polymodal sensory synthesis, plays an important role in the analysis of the behavioral significance and the novelty of stimuli (Heilman et al., 1987). The inferior parietal lobule, particularly, plays a critical role in this process. Because it has strong reciprocal connections with the polymodal areas and the limbic system, if damaged, it may impair the subject's ability to detect the significance of a stimulus. It should be noted here that stimulus significance and processing are partly influenced by the motivational state of the organism, e.g., needs, long-term goals, etc. (Heilman, 1979; Heilman et al., 1987; Mesulam, 1981). Heilman et al. (1992) suggest that these polymodal areas may also have connections that project to the MRAS and to the NR. This may induce a more general inhibitory action on the NR and enhance transmission through the thalamic relay nuclei, or may induce a general state of arousal because of diffuse multisynaptic input to MRAS, or both. Accordingly, a lesion in one of these areas leads to the inability of a patient to be aroused by, or to process, multimodal contralateral stimuli.

Research results by Segundo, Naguet, and Buser (1955) (as cited in Heilman et al., 1992) indicate that stimulation of selected polymodal sites of cortex, such as the frontal cortex and the superior temporal and inferior parietal lobe, induces a generalized arousal response. It was also reported that when similar sites are ablated, there is EEG evidence of ipsilateral hypoarousal (Heilman et al., 1992).

According to what was mentioned earlier, a lesion in the MRAS leads to indirectly inhibiting the thalamic relay nuclei, hence, to the inhibition of any type of sensory input (whether visual, auditory, or sensory) from reaching the cortex. In addition, a lesion of the posterior parietal cortex tends to block the multiple unimodal inputs converging on it (De

Renzi et al., 1989). Consequently, the attention-arousal model (of Heilman) and the theory of network dysfunction (of Mesulam) assume sensory neglect as a multimodal (supramodal) phenomenon, which affects the detection of contralateral stimuli, whatever the sensory channel through which they are transmitted. This explains the cases of supramodal spatial neglect often found in the literature.

Cortical remote effects of decrease in cerebral blood flow (CBF) or metabolism due to a reduction in cortical neuronal activity have frequently been observed in the cortex ipsilateral to deep-seated lesions. (Hublet, Demeurise, Paternot, Colson, & Capon, 1995). Based on this observation Hublet et al. (1995) studied this effect in a population of 13 stroke patients, using cerebral blood flow measurement methods. Seven patients manifested visual neglect on the assessment using a neuropsychological battery of tests. All patients showed regional cortical hypoperfusion. However, in patients with visual neglect, it was more extended and involved the right inferior parietal region. The results supported the two assumptions concerning the pathophysiology of neglect on which Hublet et al. based their study. First, the results suggested a causal relationship between cortical dysfunction and the occurrence of neuropsychological disorders such as visual neglect. Second, the results supported the model proposed by Heilman and his coworkers that neglect is attributed to a unilateral attention-arousal defect provoked by a lesion interrupting a corticolimbic-reticular loop in which the parietal cortex and particularly the inferior parietal lobule play a critical role.

<u>Hemispheric Asymmetries</u>

Before we look at some examples of the findings in the literature that are relevant to the current study, it is relevant to expose here the hypothesis of hemispheric asymmetries.

As mentioned earlier, the extent and severity of neglect after left hemisphere lesions is far less than the neglect resulting from lesions in the right hemisphere. For example, Mesulam (1981) cites an experiment by Chain, LeBlanc, Chedru, and Lhermitte (1979) "who measured the distribution of attention by quantifying the amount of time spent looking at each sector of a projected picture" (p. 321). The results showed that some patients with lesions in the left hemisphere showed visual neglect of the right side, mostly during the first five seconds of viewing. In contrast, many patients with right hemisphere lesions continued to neglect the left side for 15 seconds, and they spent virtually the entire viewing period looking at the far right side of the picture and avoided its extreme left aspect.

Heilman et al. (1992) and Mesulam (1981) agree on a similar explanation concerning this functional asymmetry. Their models are based on some common assumptions. First, they proposed that the neurons designed for attentional functions (comparative cells according to Heilman) in the intact right hemisphere may attend to both sides of space with the predominant tendency being for attending to the contralateral (left) hemispace; in addition, more synaptic space is devoted to attentional functions in the right hemisphere than in the left (Mesulam, 1981). Consequently, novel or significant stimuli in either or both sides would activate the right hemisphere (Heilman et al., 1992). Second, the left hemisphere would be activated predominantly by novel or significant stimuli on the contralateral (right) side because cells in the hemisphere are more likely to be concerned (have receptive field) with attending only to the contralateral (right) hemispace (Mesulam, 1981). So when the left hemisphere is damaged, subjects can still attend to the right because the right hemisphere attends to either or both hemispace. By contrast, in the absence of similar compensatory mechanisms in the left hemisphere, right hemisphere lesions will result in marked unilateral neglect, but attending to the right remains possible because the intact left hemisphere continues to be activated by stimuli on the right.

In support of his assumptions, Mesulam (1981) cited the findings of Dimond (1976, 1979) in which the right hemisphere performance was found to be superior in tasks of vigilance as indicated by the results of separate testing of each hemisphere in a group of split-brain patients. Furthermore, Mesulam found that confusional states emerged especially after right hemisphere lesion. In some patients the right hemisphere predominantly modulated even ipsilateral attention. This evidence has been held to support a bilateral attentional function for neglect on the assumption that confusion represents bilateral neglect.

This evidence of confusion is controversial. Kinsbourne (1987) argues that confusional states may follow left-sided infarction but its expression may be masked by verbal aphasia accompanying these types of lesions. He further debates that the characteristic features of confusion, such as disorientation for place and time, memory deficit and confabulation, illogicality, delusions and hallucinations were not found to be associated with the symptoms of severe unilateral neglect.

Research Findings

There are various theoretical accounts with respect to the nature of the underlying mechanisms of USN. Some, such as Heilman and coworkers, consider neglect to be a unitary syndrome (supramodal hypothesis) others, such as De Renzi and coworkers, consider neglect to be mutually exclusive manifestations (unimodal hypothesis). The exact relationship between the different forms of neglect is yet unclear and awaits further research. Recent research has focused on the observation that many of the patients with visual neglect also show evidence of auditory neglect, tactile neglect, and sometimes, other forms of neglect as well.

For instance, findings in the literature on caloric vestibular stimulation of the external ear canal are in support of the supramodality hypothesis. Vestibular[4] stimulation, in patients with RHD, is a procedure of introducing cold water to the contralateral ear (left) or warm water to the ear ipsilateral (right) to the lesion producing a slow phase of nystgamus with leftward eye deviation (Vallar, Rusconi, Barozzi, Bernardini, Ovadia, Papagno, & Cezarani, 1995).

Storrie-Baker et al. (1997) investigated the effects of caloric stimulation on the deficits in spatial exploration that accompany hemispatial neglect. In their study they used the cold-water calorics as an electrophysiological test of the arousal hypothesis of neglect. A case study on an 83-year-old woman with stroke due to a cerebrovascular accident (CVA) in the right-hemisphere was presented. In addition to severe hemispatial neglect, the patient exhibited rightward head and eye deviation, left hemiplegia, left homonymous hemianopia, and left hemianesthesia. Introducing ice-water to the left ear produced a temporary partial remission of neglect symptoms. For example, her line bisection error was attenuated by over 80%. Similarly, her performance on the vigilance task also became regularized. Vestibular stimulation also produced leftward eye deviation to central position associated with significant changes in EEG activation. In addition, the EEG also indicated a general increase in arousal, shown by central activation of the cortex, and an increase in cortical activation in both hemispheres, with significantly greater activation of the right hemisphere. These findings of Storrie-Baker et al. (1997) support the attention-arousal

hypothesis proposed by Heilman and his colleagues, whose model predicts that following vestibular stimulation an alleviation of the right-hemisphere hypoarousal would occur in the context of a decreased left-hemisphere arousal level. Also this model assumes USN to be a supramodal phenomenon.

The effects of caloric stimulation on other neglect-related deficits have also been examined in the literature. For example, Vallar et al. (1993) reported earlier studies (e.g., Vallar et al., 1990) in which left visual hemispatial neglect, tactile hemianesthesia and anosognosia for left hemiplegia showed temporary improvement following caloric stimulation. Based on their observations, Vallar et al. (1993) implied that both deficits, the somatosensory neglect and unilateral spatial neglect (extrapersonal), can be associated and may be explained by a common underlying mechanism. They suggested that right hemisphere lesions produce "a rightward pathological deviation of conscious" body or egocentered representations of extrapersonal space and body parts.

Subsequently, Vallar et al. (1993) found that unilateral somatosensory deficits or tactile neglect contralateral to the lesion could be temporarily reduced with vestibular cold-water stimulation. Tactile neglect improved in 88% of right-hemisphere damage

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[4] "The vestibular system is a component part of cerebral circuits, including cortical and subcortical structures, involved in maintaining orientation in egocentric space with

patients after vestibular stimulation; the majority of these patients with RHD (13/15) had some visual neglect symptoms; and the remaining two patients with RHD (one with and one without visual neglect) did not show any improvement after stimulation. In contrast, vestibular stimulation was effective in alleviating right somatosensory deficits in only 18% of patients with left hemisphere damage and those showed signs of right hemispatial neglect. This reflects a "non-sensory" perceptual component of somatosensory extinction and may be a manifestation of left USN, since improvement showed a right asymmetry. As the results showed, the majority of the patients who improved after vestibular stimulation had right hemisphere lesions. This perceptual rather than sensory deficit is clearly stated in the following citation in Vallar et al. (1993):

> Primary sensory analysis of lateralized tactile stimuli is primarily performed by the contralateral hemisphere, without left-right asymmetries. Its main cortical correlate is likely to be the anterior parietal lobe (Corkin et al., 1970; Pause et al., 1989). The processes related to conscious perception of somatosensory stimuli are, by contrast, organized in a non-symmetric fashion. Their neural correlates are likely to include regions such as the posterior parietal lobe, involved in the representation of personal and extrapersonal space (Vallar & Perani, 1987, Stein, 1989, Vallar, 1993). (p. 77-78)

These findings are in accord with the network assumption of Mesulam (1981), in which the inferior parietal lobe plays an important role, and which can explain the association of

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reference to the body." (Howard & Templeton, 1966, 1982; as cited in Vallar et al.,1993) somatosensory deficit to hemispatial neglect. Within this network framework, the results support a supramodal concept of perceptual neglect.

Also, Bisiach, Rusconi, and Vallar (1991) stated that mental representations, measured by descriptions of landmarks from memory using a variety of specified vantage points, also showed improvement with vestibular activation.

Some other research considered the supramodal and hypoarousal hypotheses by investigating the presence of the relation between both auditory and visual neglect. Early research by Heilman and Valenstein (1972a) into auditory neglect, which was assessed by double simultaneous stimulation, cast doubt on the modal specificity of USN. In their research, they demonstrated that among 10 patients with brain damage, nine had the locus of the lesion responsible for auditory neglect in the right inferior parietal lobe, while one had it in the left frontal lobe. All the cases showed evidence of the other neglect phenomena, including visual and tactile neglect as evidenced by extinction to simultaneous tactile and visual stimuli, in addition to anosognosia and anosodiaphoria.

Similar findings were observed in early studies by Denny-Brown et al. (1952) in which somatesthetic and visual neglect were associated with all the cases of auditory neglect reported in humans. Somatesthetic and visual neglect without auditory neglect had been studied by several investigators (Brain, 1941; Critchley, 1949; McFie, Piercy, & Zangwill, 1950; as cited in Heilman & Valenstein, 1972a), and had also been associated with parietal lobe lesions. Heilman and Valenstein (1972b) also reported six cases of frontal lobe neglect in humans, and these patients demonstrated visual and somatesthetic neglect but no auditory neglect.

Other studies were in favor of the unimodal hypothesis of USN. For instance, De Renzi et al. (1989) investigated auditory neglect and its relation to visual neglect. The patients, with recent unilateral hemispheric lesions, were required to detect the interruptions that occurred at one ear in a sound delivered through earphones either monaurally or binaurally. In the study, auditory extinction was also detected in a second task demanding sound-signal detection during bilateral simultaneous stimulation. In addition, visual neglect was also investigated. Among 30 patients with RHD, 16 patients showed visual neglect and nine patients manifested auditory neglect. All of the nine patients with auditory neglect were significantly impaired in the binaural test. Of these, seven were also significantly impaired in the monaural test, but with a markedly increased number of omissions on the binaural test. Neglect was constantly prevalent in the contralateral (left) ear in the binaural test. Moreover, the underlying lesions responsible for the neglect were mostly localized in the right parietal and right thalamic regions.

Of relevance to the current study was the finding that, in the last study cited, auditory neglect was not consistently correlated with visual neglect. In fact, on the one hand, auditory neglect was not present in nine of the patients showing visual neglect and two of the nine patients with auditory neglect did not show any visual neglect. Hence, the outcome of De Renzi's study is at variance with a supramodality assumption since neglect did not necessarily involve visual and auditory manifestation.

On the other hand, auditory neglect was not found to be consistently correlated with auditory extinction, since two of the nine patients who manifested auditory neglect did not show any auditory extinction. In their study mentioned earlier, De Renzi et al. (1984) found no correlation between the severity of extinction in the auditory and visual modalities. According to Soroker, Calamaro, Glicksohn, and Myslobodsky (1997), the findings of De Renzi et al. "point to the existence of intra-and intermodal double dissociation in USN" (p.250). This double dissociation is between auditory neglect versus auditory extinction on the one hand and auditory neglect versus visual neglect on the other hand.

It is worthwhile noting that spatial analysis of sounds involves the localization of sounds in the environment (source of sound) and the lateralization of sound fed into both ears from different channels. Usually in exploring disorders of perceived auditory localization the free-field dichotic method is used as a mean of assessment. In the free-field condition, the sound is delivered through a loudspeaker. While, when exploring disorders of perceived auditory lateralization, the Dichotic Listening technique is usually used as a mean of assessment (Bisiach et al., 1984).

In a study of audiospatial abilities following unilateral hemisphere damage, Bisiach et al. (1984) presented pure tones dichotically, with varying interaural intensity differences[5]; the patients were asked to localize the direction of the sound heard. Patients having LHD and RHD with intact visual fields performed normally in this task; on the contrary the performance of all patients having RHD with visual-field defects (with or without visual neglect assessed by Line Cancellation Task) was impaired and showed a systematic directional error to the right. The finding that only patients having RHD with visual-field defects showed a systematic directional error to the right indicates

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[5] " In Dichotic Listening lateralization is obtained either by interaural intensity differences (ΔI) or by interaural time differences (Δt): the fused sound image is perceived as lateralized towards the ear which receives the more intense or leading stimulus." (Bisiach et al., 1984; p. 38)

hemispheric asymmetry. In this earlier study of Bisiach et al. (1984) the investigators attributed this systematic error of auditory lateralization to the distorted representation of the egocentric space to the right. In addition, the presence of auditory lateralization was found to be independent of the presence of visual neglect. The authors suggested two explanations for the latter finding. First, they attributed it to the fact that the Line Cancellation Task is less sensitive than the Dichotic Listening task. Thus, auditory neglect would be more easily detected than visual neglect; it follows that in a number of patients with auditory neglect, even if they have visual neglect, it would remain undetected. Second, they noted that the inconsistency of the correlation between auditory lateralization and visual neglect found in their patients might be due to the site of the lesions involved in their sample of patients (Bisiach et al., 1984). This issue will be discussed further later on. The finding of Bisiach et al. that error in auditory localization "to the right side involves not only contralateral but ipsilateral half-space" (p. 48) was also explained by Kinsbourne (1987) as being due to a directional bias in the "print-out" of the representation. The process of internal representation is sequential and influenced by the same directional biases as are the processes of attentional shifts across the external space. The attentional bias manifests itself at the levels of abstract representation (images) of spatial orientation as well as at the level of the fully-fledged syndrome of rightward bias in attention and evaluation of self and external space (percepts).

Similarly, the interaction between audiospatial and visuospatial information processing in neglect was investigated in a study by Soroker et al., 1997. They investigated the presence of auditory inattention in patients having RHD with visual neglect (N+) and without visual neglect (N-), using free-field bilateral simultaneous stimulation (BSS) and pseudorandom (single-blinded) unilateral stimulation. The fact that the blindfolded subjects did not know the order and localization of stimulus presentation would limit the possibility of shifting their gaze toward the direction of the sound. This shift in gaze would interfere with stimulus identification by improving localization of left-sided stimuli. Three major findings were reported. First, both N+ and N- groups exhibited auditory neglect. Both N+ and N- groups extinguished left-sided sound stimuli in the BSS condition and performed abnormally (showed significantly more frequent extinction of left- compared to right- sided sound stimuli) when auditory stimuli came from the left in a task demanding stimulus identification. Second, blindfolding significantly improved the localization performance. All in all, the emergence of contralesional auditory neglect does not depend upon the existence of neglect in the visual modality. Third, compared to normal individuals, N+ patients showed superior ability to localize sounds on the right side. This is in accord with Kinsbourne's (1987) assumption of a right attentional bias in normal individuals and the conception of left-sided neglect as reflecting a pathologically exaggerated form of this attentional bias towards the right. Failure to attend contralesionally is complemented by exaggerated attention in the ipsilateral (intact) direction. Finally, Soroker et al. (1997) discussed their results in the context "of spatial attention as based on a system containing both supramodal-and-modal-specific components." (p. 255)

These findings of Soroker et al. (1997) were similar to those found in a study by Farah, Wong, Monheit, and Marrow (1989). Using a variant of Posner's task (mentioned earlier), Farah et al. compared the reaction time of patients with visual neglect and right parietal damage to lateralized visual targets. These targets were precued either by non-predictive lateralized visual cues or by non-predictive lateralized auditory cues. The cues were non-predictive because they appeared on both the target side and the opposite side in equal proportions. Farah et al. found that the slowness or impairment in the patients' ability to disengage spatial attention from an ipsilesional stimulus to a contralesional stimulus was observed with both visual and auditory precueing signals. Furthermore, they suggested that the fact that the allocation of attention to visual targets was affected by auditory stimuli that occurred at other locations indicated that the parietal lobe attentional mechanisms operates in a supramodal representation of space where both visual and auditory are present.

Conversely, based on the McGurk illusion model, Soroker and colleagues studied audiovisual neglect (Soroker et al., 1995a; 1995b). The Mcgurk illusion (McGurk and MacDonald, 1976; as cited in Soroker et al., 1995a) is an illustrative case of intersensory bias. The McGurk illusion, an audio-visual blending, is elicited when a visual consonant-vowel (CV) syllable (e.g., ga) is presented in combination with a conflicting auditory CV syllable (e.g., ba) and yields a blend percept (e.g., da). The blend percept occurs with no awareness of conflict in the majority of the normal population (Soroker et al., 1995a).

The earlier of those studies was effectuated by Soroker et al. (1995b) in a group of 6 right hemisphere damage patients with both left visual and auditory neglect. Auditory neglect was assessed using free-field stimulation through a loudspeaker on the left side. Soroker et al. showed that, when a patient sees a ventriloquist (a dummy loudspeaker) placed in the ipsilateral space moving his mouth in accord with the sounds the patient is receiving in the contralateral ear, his ability to identify the syllables is significantly enhanced. The results were indicative of a strong coupling between auditory and visual systems. Also, visual cues or the manner of articulation in ipsilesional (right) space can influence the perceived place of articulation of syllabic sounds; the ventriloquist effect helps a patient with auditory neglect to mentally reconstruct syllabic sounds voiced in the left (neglected) space. Soroker et al. (1995b) attributed this effect to the activation of the audio-visual map in the left hemisphere by the fictitious source of sound. The authors have cited previous studies of examples of intersensory bias whereby a coupling between auditory and visual spatial-attentional systems was found. De Renzi, Faglioni, and Scotti (1970) (as cited by Soroker et al., 1995b) showed that change of eye gaze posture and direction of eye fixation might interfere with sound identification. In exploration of supramodal neglect, for example, the patients' performance during Dichotic Listening is enhanced when the eyes are fixated in the direction of the relevant inputs (Reisberg, Scheiber, & Potemken, 1981; as cited by Soroker et al., 1995b). Hence, it was important in this study to test participants separately for each modality.

The results from these studies on audiospatial versus visuospatial deficits following brain damage are sometimes equivocal regarding intermodal correlation. However, the general dominance of findings that support a correlation indicates that the conception of USN as a disorder of dysfunction in a network, where a supramodal processing of sensory information occurs, cannot be disregarded and is worth investigating. The aim of the present study is to investigate the presence of left auditory neglect in a patient exhibiting left visual neglect following a right-hemisphere stroke. If neglect means failure of a supramodal system for spatial attention, due to a strong intersensory bias, a coupling between auditory and visual spatial-attentional systems would be expected.

In this case study, the supramodal hypothesis is investigated, using updated versions of the Tachistoscopic Presentation and the Dichotic Listening techniques. The importance of the present study lies in two shortcomings of the literature discussed. One aspect is the scarcity of investigations of audio-visual neglect. The other aspect is that none of the studies discussed above used both Tachistoscopic Presentation and Dichotic Listening as complementary methods in testing for visual and auditory neglect.

CHAPTER II

Method

Participants

Two male adults of age 60 participated in this study. One patient with a right hemisphere stroke and a control participant with normal hearing were tested. The patient and the control were matched in terms of age, gender, educational background, and mental ability.

Case Report

The patient was referred to us after his admission to hospital in Beirut. T. A., a 60-year-old, right-handed man, hypertensive and diabetic, presented to the ER with collapse following right-sided headache. He was admitted to the hospital as a cerebrovascular accident (CVA) stroke patient. On admission he exhibited left hemiparesis, left facial paresis, left hemianesthesia, left upper quadrant hemianopia with no nystgamus. He exhibited also rightward eye and head deviation. He showed signs of confusion, as characterized by disorientation for place and time, and memory deficit. In addition, he exhibited low vigilance and arousal. He stayed in the intensive care unit (ICU) for 5 days. Over subsequent days the patient became more alert and oriented to time, place, and person but was easily distracted. He spoke more or less normally, named, repeated, and followed commands.

History

The patient had been functionally independent prior to the stroke. According to the patient's wife in an interview, he collapsed at work. He had worked as a cook for the last three years. He had ten employees. Before that he had held a succession of jobs, and he had had periods of unemployment. These periods varied between 2 and 9 months. According to his wife, during those periods he was very irritable. He has a very limited level of education, the fifth grade. He has limited reading and writing skills. He is married with children.

Neuroradiological and Neurological examinations

Scans and Neuroradiological Examinations.

1. A CT scan performed the first day of admission showed an ischemia of 2 cm at the level of the right basal ganglia. A similar but smaller ischemia was found at the level of the tip of the right temporal lobe. In addition, a left temporal arachnoidal cyst appeared.

2. A second CT scan performed the second day at ICU showed an increase in the size of the ischemia in the right temporal parietal lobe with a mild edema of 1 cm, this was in addition to a mass effect in the middle cerebral territory.

3. A CT scan performed 5 days after admission showed a large middle cerebral artery territory infarction involving the right fronto-temporal lobes. No bleeding.

4. The results of an MRI, effectuated at follow up, 6 months after the accident, confirmed frontal, parietal, and temporal damage of the right hemisphere extending to the postcentral gyrus, the superior temporal gyrus, and the inferior parietal lobule.

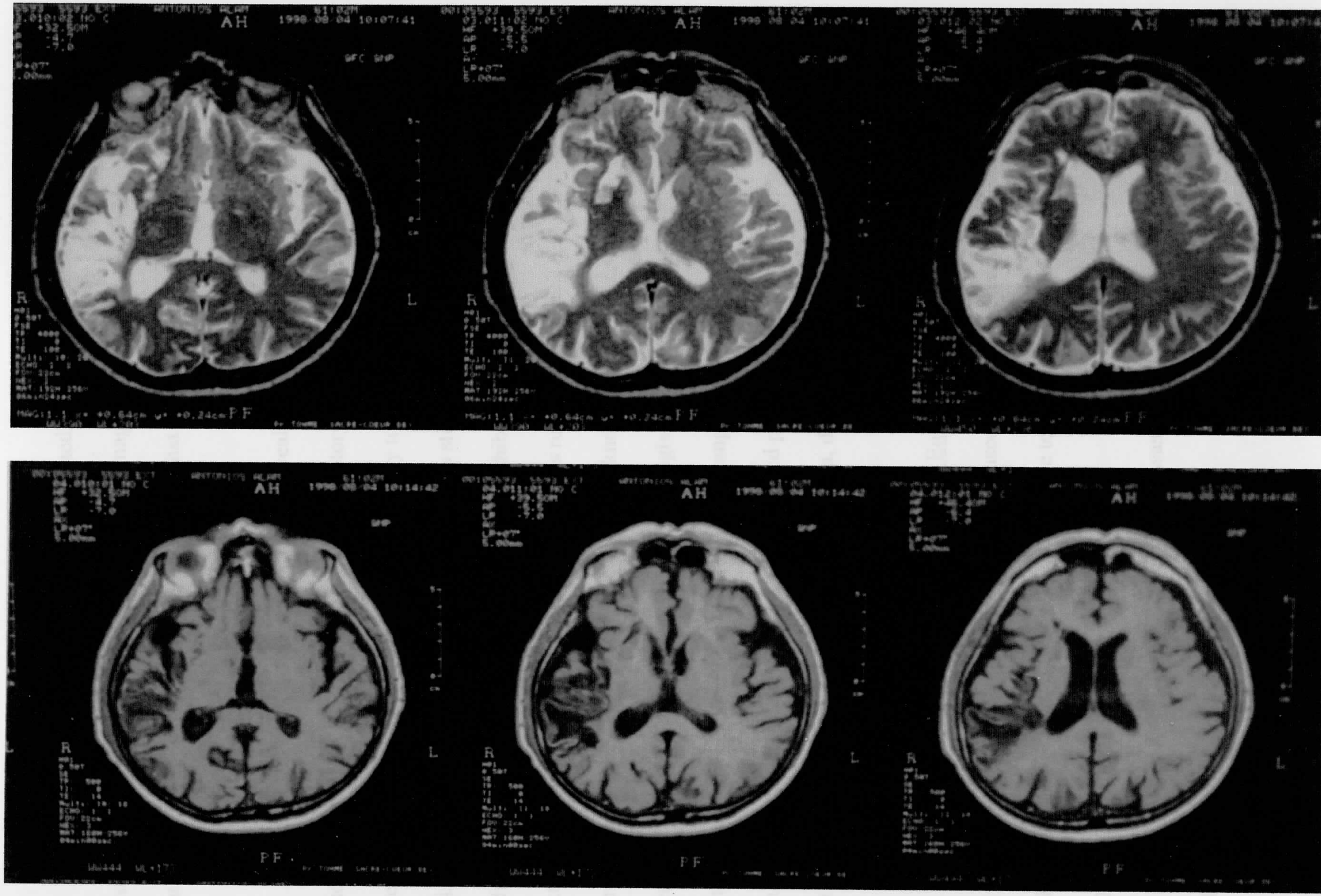

Figure1. The MRI of T.A.'s brain showing a deep right CVA of the middle cerebral artery involving the frontal, parietal and temporal lobes.

5. Auditory Evoked Potential was effectuated one month following the stroke. The results of the EP were normal, indicating no damage in the sensory auditory tracts. The patient was tested audiometrically to ascertain that he had normal hearing.

Clinical Neurological Examinations.

Bedside neurological examination also revealed somatesthetic extinction, and left auditory extinction. Bedside assessment of auditory neglect by finger snapping started by presenting stimuli separately and simultaneously to each ear. The patient consistently missed the left side when bilateral simultaneous stimulation was effectuated; he exhibited left auditory extinction. Upon tactile BSS he exhibited left hemianesthesia (left tactile extinction). His perception of pin and touch was reduced on the left. For instance, when pinched he exhibited a sign of distress without knowing the source of it. Subsequent neuropsychological examination by the neurologist indicated left asomatognosia and left astereognosia. Astereognosia is the partial or complete inability to recognize objects by touch (Reber, 1995). The patient also manifested pain hemiagnosia when pinched on his left arm. Further examination excluded dyslexia, dysgraphia, apraxia, and aphasia.

Procedures and Equipment

The same sequence and procedures were used with both research participants. The following description and remarks pertain to the testing sessions with the patient.

The Tachistoscopic Presentation.

The Tachistoscopic Presentation method was used to assess visual neglect. It was effectuated eight days poststroke.

Stimuli were generated by a PC computer, which was installed in the patient's hospital room. The patient was in his bed in the sitting position with his eyes approximately 50 cm from the screen. The middle of the screen approximately corresponded to the middle (midsagittal) of the patient's head. The examiner used the computer's keyboard to record the patient's responses and to initiate trials. The test was composed of two tasks: a simple task and a complex task. The patient was given the following instructions.

Instructions for the simple task. The patient was asked to look at the screen in front of him, and told that he was going to see this symbol (Λ) displayed at different locations on the screen (upper left, lower right, center, upper left, and lower right). He was shown the symbol written on a white A4 paper. The paper was placed in the patient right visual field. Then, he was instructed to point, using his right index finger, at the places on the screen where he saw these symbols and to say how many there were at each place. Pointing with the finger was used instead of verbal responding to safeguard against confusing answers.

On both the simple and the complex task the participants were instructed to fixate their eyes on a certain midpoint on the screen. This condition was observed for all trials.

Instructions for the complex task. This time the patient was told that in addition to the symbol he saw during the first task, two other symbols (ר , ט) would appear at different places on the screen. But he was instructed to point only to the symbol (Λ) . The patient was also shown the three symbols drawn together on a white A4 paper and the two symbols which were not the target of responding were crossed out with a pen in front of the patient. The paper was placed in the patient's right visual field. For the rest he was given the same instructions as in the simple task.

Each task was effectuated in three series. The series differed from each other in terms of exposure duration (about 150, 300 and 1000 ms). Each task began with a brief practice trial (at 500 ms) to ensure that the task was thoroughly understood. Each session was composed of 18 trials. The target symbol appeared all in all 23 times in each hemispace of the screen and eight times in the center of the screen. The examiner controlled the appearance of the symbols on the screen. No time limit was set for the response, and a new stimulus was presented only after the patient had made his response or acknowledged his inability to identify the stimulus. On each trial the examiner would ask the patient if he was ready and then initiate the next trial. Prior to executing each trial, the examiner said "now, ready?" to ensure that the participant was ready and attentive.

The patient was supposed to identify the target symbol anywhere on the screen. For every target identified the examiner pressed a key on the keyboard corresponding to the indicated emplacement of the stimulus on the screen, in accord with the software's program for encoding and scoring. Also, an assistant recorded the responses manually on a record sheet.

<u>Observations</u>. The patient was drowsy. He was given the instructions and the test started with a pretest exposure series (500 ms) of the simple task. The patient could not identify the target; it took him three trials to identify it. Afterwards, the simple task was started beginning with the 150 ms exposure series. The patient looked away, and he was not able to notice the stimuli. Apparently, the duration of the display of the stimuli was too fast for him in his fatigued state. A break was given. This time the test was started again

beginning with the 1000 ms exposure series, which motivated him to cooperate and go on with the test. Then the test continued with the 300 ms series and ended with the 150 ms series. In the complex task also he was given the three series 1000 ms, 300 ms, and 150 ms, respectively. The patient had problems concentrating long. He was reminded constantly to focus on the screen. The tasks went on regularly except for four to five trials when the patient showed some signs of tiredness and sometimes closed his eyes or looked away to rest for a few minutes. On several occasions, he leaned his head to the right, so I had to adjust his posture. However, he insisted on finishing the test and was cooperative. It is worthwhile noting that the patient did not point at non-target stimuli in the complex task. In addition, he tried to press the on-off button on the right of the screen three times and was looking for his wife, which were signs of distractibility. On some of the trials (3-5 times), he did not point at the target but looked at its location. When in these cases he was asked to point out what he saw, he pointed at the right place. Throughout the test the patient never complained about any vision problem. The patient recognized his wife, nurses and friends. He understood the instructions easily.

Then the patient was given the first part of the awareness interview for anosognosia. The administration of the first part of the interview required 7 min. The Dichotic Listening testing was postponed to a different day because the patient appeared drowsy and tired.

<u>Dichotic Listening</u>

The Dichotic Listening was administered 2 days after the Tachistoscopic testing, in the hospital at bedside. The patient was awake and was able to lift his left hand about 20 cm off the bed.

The dichotic tape consisted of digitized natural speech with the syllables /ba/da/ga/pa/ta/ka/ presented under three attentional instructions (Hugdahl & Anderson, 1986). A computer system was used to attain exact temporal alignment of the onset of the left and right ear stimulus. The intertrial interval between stimulus presentations was about 4 s. The six consonant-vowel (CV) syllables were paired for all possible combinations, yielding 36 DL trials, including the six homonyms (ba-ba, etc.). The Dichotic Listening technique was effectuated according to the instruction of the Manual of Dichotic Listening with the CV syllables (Hugdahl & Andersson, 1990). The instructions were to repeat the heard syllable; freely in the non-forced condition, selectively from the right ear in the forced-right condition, or selectively from the left ear in the forced-left condition. The patient was given the instructions before each task. The order of presentation of the three conditions was fixed; the non-forced condition first, the forced-right condition next, and the forced-left condition last. The homonyms were used for test trials and excluded from statistical analysis. Thus there were 30 pairs of CV syllables for scoring for each of the three attentional conditions. Left and right ear scores were calculated for each condition, on the basis of the number of correct reports from each ear. The CV syllables were played to the respondent from a radio cassette tape recorder through headphones at a sound intensity level indicated by the respondent to be a comfortable listening level. The participant either made a response of repeating the heard syllable or admitted hearing nothing.

All through the testing sessions, the patient was continuously monitored for any distraction or discomfort. This was to ensure for continued attention and full cooperation.

Instructions. Before the test started, the patient was informed that he would be listening to six syllables through headphones. The syllables were shown to the patient printed, in Arabic equivalent with a font size of 14, on an A4 white page. In the non-forced recall condition, he was asked to report after each presentation which syllable he heard. He was also told that he would sometimes experience hearing two sounds at the same time and he should not worry about it. However, he should try to report the sounds that seemed most clear to him, and he should try not to hesitate whenever he heard a specific sound, and just report it loudly after each presentation. No specific instruction concerning allocation of attention between ears was given.

In the forced-right condition, the patient was asked to direct his attention to his right ear, and report the sounds he heard only in the right ear. This bit of instruction was accompanied by pointing to the patient's right ear. The patient was also asked to ignore the left ear sounds and concentrate only on the sounds he heard in the right ear.

The same instructions were given for the left ear in the forced-left condition. In the forced-left condition, the patient was told that he should only attend to and report what he heard in the left ear, ignoring the right ear input. The instructions were otherwise identical to the instruction given in the forced-right condition.

The purpose of the test was to compare frequency of correctly reported CV syllables from the right and left ear during a non-forced, forced-right, and forced-left attentional condition. If the patient had left auditory neglect, it would be expected that he would report more correctly from the right than the left ear compared to the control participant through all the three conditions: Forced-right condition, forced-left and free-recall. To keep a record of the participant's responses, the examiner also wore earphones, and an assistant, not wearing earphones, marked the patient's answer after each trial on a response sheet.

Observation. As stipulated in the instructions in the manual of Dichotic Listening (Hugdahl & Anderson, 1990), a paper containing the syllables (but in Arabic) was placed in the patient's right visual field. Because of the patient 's limited reading capacity, discerning the corresponding written syllable in the limited time allowed interfered with his ability to follow the succession of the heard syllables. The DL was run without the syllables being in front of the patient. This produced better responding and less confusion. The patient did not produce any confabulatory responses. The patient was willing and cooperative but seemed tired with the procedure. The procedure was interrupted two times due to external factors (nurse, electricity cut), so the trials were repeated. Sometimes the patient did not give any answer. During a couple of trials he kept looking for his wife. This produced some signs of distractibility. Other than that the procedure went smoothly.

IQ Testing

General intellectual ability was assessed with the verbal part of the Wechsler Adult Intelligence Scale. Scaled scores of the WAIS-R Vocabulary subtest provided an estimate of the Full Scales IQ (FSIQ) but can by no mean be considered as FSIQ (Sullivan, Sagar, Gabrieli, Corkin, & Growdon, 1989; Hublet et al., 1995). The verbal part of the WAIS-R was translated into Arabic by a linguist, and its ease and comprehensibility were verified by consensus by a number of native Arabic speakers. The vocabulary subtest was administered and scored according to the Wechsler's (1981) instructions.

The Awareness Interview

A semistructured interview was used to examine the patient's awareness of his illness and to investigate his awareness of impairments in areas including perception, intellect, language, and motor functioning. The Awareness Interview was not administered to the control participant.

I used a modified version of the "Awareness Interview", a standard procedure, by Anderson and Tranel (1989). My primary aim was the evaluation of anosognosia for illness and visual neglect; hence, the interview was modified accordingly. The questions were translated into Arabic and tested on some participants for clarity of language and ease of comprehension.

The Awareness Interview (see the Appendix) comprises seven sections and is divided into two main parts. Part one, containing sections A and B, was administered to the patient at the end of the first testing session following the Tachistoscopic Presentation. It was administered at the end rather than at the beginning, so that rapport would have been developed between the patient and the examiner. Sections A and B investigate the extent of awareness of illness and awareness of motor impairment, respectively. The second part of the interview, Sections C to F, was administered following completion of the neuropsychological evaluation (DL and TP). The patient was asked whether he had acquired deficits in certain cognitive functions, including visual perception, general thinking and intellect, speech and language, and was asked to judge the quality of his performance on the DL and TP tests.

The examiner used the specific questions decided upon, and repeated the questions when needed or pursued further questioning if the patient's answer was not adequate.

Scoring of the Awareness Interview. All responses were scored by the examiner on a 3-point scale according to criteria described in the Awareness Interview that is based on the study of Anderson and Tranel (1989). (For details see the Appendix).

Deviation scores were calculated for each question. Deviation scores reflect the awareness of the patient of certain areas of impairment since each score is a comparison of the patient response pertaining to impairment in a certain area of functioning with his actual neurological and neuropsychological profile. The deviation scores would vary between 0 and 2, zero indicating a match between the patient's answer and the examiner's evaluation. On the other hand, a deviation score of 2 would indicate a maximum discrepancy between the patient's answer and the examiner's evaluation. Hence, a deviation score of 2 indicates unawareness on the part of the patient of his impairment in the area investigated.

Deviation scores for section A, which is not directly related to performance on the neuropsychological test, were calculated as follows. The scores on the seven questions (1-7) that compose section A were added to obtain an average deviation score. The scoring of the answers was as follows. A score of 3 was given if the patient explicitly denied impairment in the investigated area related to his illness. A score of 2 was given if the patient admitted but did not initially state the existence of impairment in the investigated area related to his illness. A score of 1 was given if the patient accurately described the impairment in the investigated area related to his illness. For example, if the patient described accurately the primary reason for his hospitalization, he received a score of 1 on the 3-points scales.

In section B (question 8) the deviation scores of awareness of motor defects were calculated by comparing the ratings of the patient's responses on the Awareness Interview with his actual neurological condition as indicated by ratings of motor function by a clinical neurologist. Normal motor function coincides with standard neurological motor strength indexes of 4-5 and an impairment score of 3. Mildly defective function coincides with standard neurological motor strength indexes of 2-3 and an impairment score of 2. Severely defective motor function coincides with standard neurological motor strength indexes of 0-1 and an impairment score of 1.

For the rest, sections C to E, the awareness of impairment was deduced by comparing the patient's responses on questions 9-11, related to the three areas of cognitive functioning with his actual neurological and neuropsychological profile. The performance in the domain of perception and intellect was measured using two neuropsychological tests, the Tachistoscopic Presentation and the Verbal IQ, while performance on language was deduced from the report of the neurological examination.

Section F was designed to investigate the patient's awareness of the quality of his performance on the DL and TP tests. The deviation score for this section was based on a comparison of the neuropsychologist's rating on a 3-point scale of the patient's overall quality of performance on both tests with his own post-evaluation rating of his performance on the tests.

At the end, the seven deviation scores on the seven sections were then added to form an Awareness Index ranging from 0 to 12. An Awareness Index of 0 indicates accurate appraisal by the patient of his condition (i.e., full agreement between the patient's self-report and the neuropsychologist's ratings), while a score of 12 indicates severe unawareness by the patient of visual neglect, hemiparesis, and the nature and implications of his condition.

CHAPTER III

Results

Tachistoscopic Presentation

The simple task

The scores on the two tasks of the Tachistoscopic Presentation (TP) represented the number of correctly identified targets in each hemispace for each series. The left and right hemispaces of the screen correspond to the participants' left (contralateral) and right (ipsilateral) visual hemispaces respectively.

Table1 shows the results obtained by both the patient and the control participant on the three exposure series of the simple task. As the table shows, during the three series (150, 300, 1000 ms) of the simple task, the patient did not identify any target stimulus in the left hemispace of the screen during any of the trials. In contrast, the control participant identified all the 23 target stimuli during the 300 ms and the 1000 ms series, and 21 of 23 target stimuli during the 150 ms series in the same hemispace.

The control participant recognized all the eight target stimuli that were displayed in the center of the screen during all of the three series of the simple task. Compared to the control participant, the patient reported seeing only 2 of 8 targets in the 1000 ms series and only 1 of 8 in each of the 150 ms and the 300 ms series.

Table 1

Performance of the Patient and the Control Participant on the Simple Task of the TP.

	Duration of Display		
HS	150 ms	300 ms	1000 ms
	Patient		
Left	0	0	0
Center	1	1	2
Right	18	16	22
	Control		
Left	21	23	23
Center	8	8	8
Right	23	23	23

Note. The values represent the number of correctly identified targets. HS=Hemispace.

Although the patient did not identify all the stimuli displayed in the right hemispace of the screen, the performances of both the control participant and the patient were more or less similar in their right visual hemispace, especially on the 1000 ms series. The control

participant identified all the 23 stimuli during the three series. By comparison, the patient identified 22 target stimuli on the 1000 ms series, and identified 18 and 16 stimuli respectively in the 150 ms and 300 ms series.

A comparison of the performance of the patient and the control participant can be seen in a graphical presentation in figure 2. The scores on both the simple in and complex task are represented in percentages to allow clearer relative comparison.

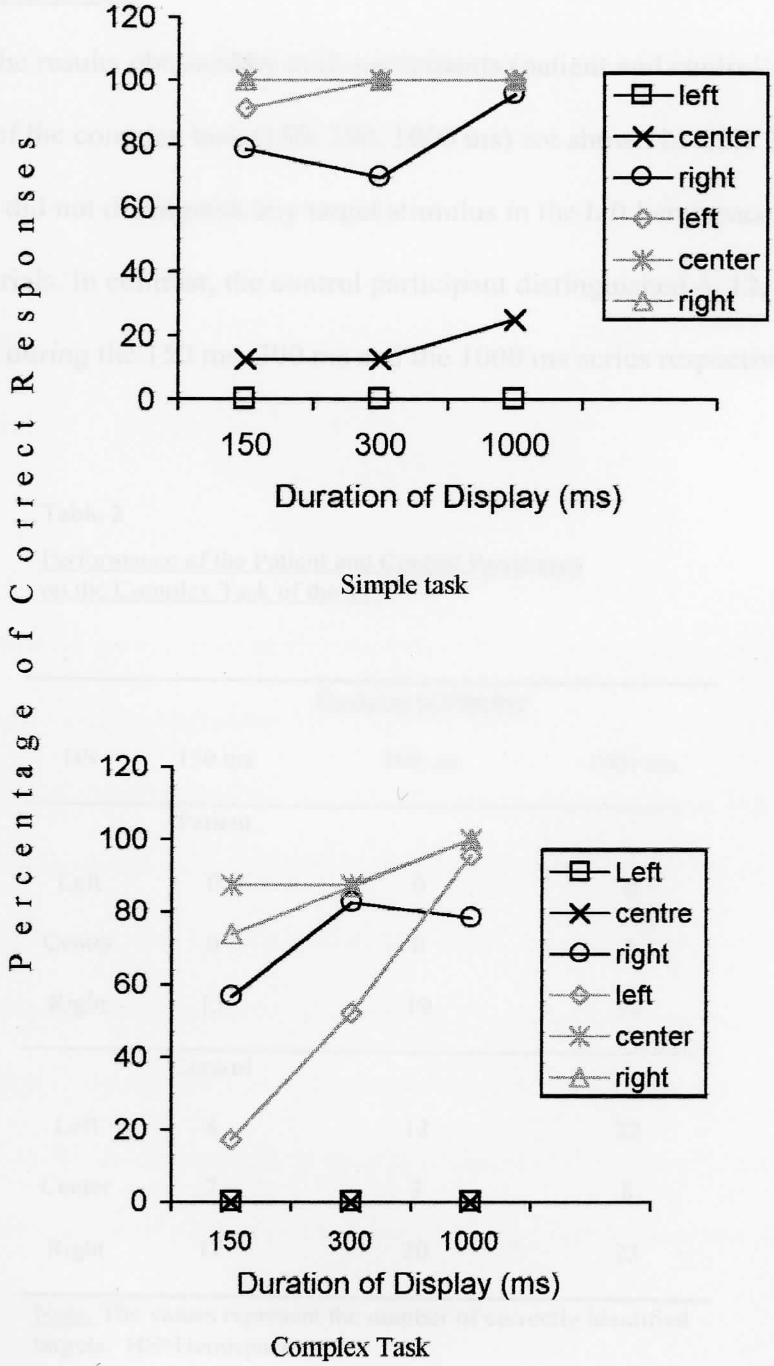

Figure 2. The percentages of correct responses obtained by the patient and the control participant, as a function of the duration of display, visual hemispace, and type of task. The patient's results are presented in solid black lines while those of the control participant's are in gray.

The complex task

The results obtained by both participants (patient and control) on the three exposure series of the complex task (150, 300, 1000 ms) are shown in table 2. As shown, the patient did not distinguish any target stimulus in the left hemispace of the screen on any of the trials. In contrast, the control participant distinguished 4, 12, and 22 of the target stimuli during the 150 ms, 300 ms and the 1000 ms series respectively.

Table 2

Performance of the Patient and Control Participant on the Complex Task of the TP.

	Duration of Display		
HS	150 ms	300 ms	1000 ms
Patient			
Left	0	0	0
Center	0	0	0
Right	13	19	18
Control			
Left	4	12	22
Center	7	7	8
Right	17	20	23

Note. The values represent the number of correctly identified targets. HS=Hemispace.

As for the 8 target stimuli that were displayed in the center of the screen, the control participant recognized 7 of 8 target stimuli in both the150 ms and the 300 ms series, and all the 8 target stimuli in the 1000 ms series. In contrast to the control participant, the patient reported seeing none of the stimuli during each of the three series.

On the other hand, the patient distinguished 13,19, and 18 of the target stimuli displayed in the right hemispace of the screen during the 150 ms, 300 ms and the 1000 ms series respectively. By comparison, the control participant distinguished all the 23 stimuli during the 1000 ms series, and 17 and 20 stimuli respectively during the 150 ms and 300 ms series.

Dichotic Listening

The data were scored as the number of correctly reported syllables during each listening condition, separated for right-and left- ear inputs. The evaluations were based on the statistical mean-scores for normative data, matching for each age available in the manual of Dichotic Listening (DL) with the CV syllables (Hugdahl & Anderson, 1990). The results of the DL test are indicated in table 3 as percentage scores and as standard deviation (SD) from the mean obtained for the normative sample. For each condition of the DL test, T-scores were effectuated for the difference between the number of correctly reported syllables obtained from each participant and the corresponding mean of the normative sample presented in the manual of DL. The homonyms were used for test trials and, hence, excluded from statistical analysis.

Table 3

Performance of the Patient and Control Participant on the Three Dichotic Listening Conditions.

	Listening Condition		
Ear	Non-Forced	Forced- Right	Forced-Left
Patient			
Left			
%	4.5	20	16.7
SD	-2	M	-1.5
Right			
%	27.3	40	30
SD	-1.25	-1.5	- .5
Control			
Left			
%	13.6	20	20
SD	-1.4	M	-1
Right			
%	31.8	43.3	50
SD	-1	-1	.75

Note. The values represent the percentage of correctly identified CV-syllables, and the corresponding SD units from the mean of the normative sample. SD= Standard Deviation units.

Non-forced (NF) condition

Regarding the left ear scores, compared to the control participant's correct reporting of 13.6 % of the syllables, the patient correctly reported 4.5 % syllables. These percentages correspond to 1.4 SD unit and 2 SD units respectively below the mean obtained for the left ear for the normative sample of the same age and sex. As shown, the patient reported only about thirty percent of the number of syllables identified by the control participant.

Examining the scores obtained for the right ear in this condition, I found that the patient's score corresponded to 1.25 SD units below the mean obtained for the right ear for the normative sample of the same age and sex. This score is also approximately 0.25 SD units below that of the control participant. The patient reported correctly 27.3 % of the syllables while the control participant reported correctly 31.8 % of the syllables heard in the right ear.

In comparing the scores of the two ears for the same participant, we find that the patient reported correctly 27.3 % of the syllables heard in the right ear while he identified only 4.5 % of the syllables heard in the left ear. The difference between the scores of the two ears for the patient is 22.8 % while that for the control participant is 18.2 %. This points toward a greater discrepancy between the auditory scores on the part of the patient.

<u>Forced-Right (FR) condition</u>

The results also showed that the control participant performed better on the right ear. The patient's score coincided with 1.5 SD units below the normative mean obtained for the same condition and the same ear, and 0.5 SD units below the control participant's score. The patient correctly reported fewer of the syllables, 40 %, compared to 43.33 % correctly reported by the control participant.

By comparing the results obtained for the left ear in this listening condition of the patient and those of the control participant, it was found that both the control participant and the patient correctly reported the same number (20 %) of syllables. This percentage corresponded to the mean obtained for the normative sample of the same age and sex.

This indicated that both participants concentrated on sounds coming from the right ear and ignored the left sounds coming from the left ear.

Forced-Left (FL) condition

On the FL condition, both participants reported correctly more items from the right ear. This can be attributed to the right ear dominance that may result in more interference from the right ear. The control participant's superior performance on the right ear over that of the patient can be explained by interference of sounds coming to that ear. The patient reported correctly 30 % of the syllables while the control participant reported correctly 50 % of the syllables heard in the right ear. These scores corresponded to 0.5 SD below and 0.75 SD above the normative mean obtained for the same condition and the same ear. On the other hand, the patient reported correctly 16.7 % of the syllables heard in the left ear while the control participant reported correctly 20 % of the syllables. When comparing the scores of the two ears for the same participant, the patient reported correctly almost half of the number of syllables heard in the left ear versus those heard in the right ear.

The patient's results on the FL condition indicated inattention to both left (contralateral) and right (ipsilateral) stimuli. However, left auditory neglect seemed stronger because the number of correctly reported syllables from the left ear coincided with 1 SD unit below the corresponding normative mean while the number of correctly reported syllables from the right ear coincided with 0.5 SD units below the corresponding normative mean.

The Awareness Interview

The overall awareness index of T.A. was 9 over 12. Sections A and B investigated the extent of awareness of illness and awareness of motor impairment respectively. The patient obtained an average deviation score of 2 on section A. This score indicated anosognosia or unawareness of the exact nature of his illness and of its implications. The patient mentioned headache as the primary reason for hospitalization. His major complaint was from his upset. Moreover, although he felt that before the hospitalization he used to see better and walk better (now he is seeing blurred), he claimed to be able to live independently. According to the neurologist's evaluation, he was unable to live independently, so he was given a score of 1 on a 3-points scale. Hence, his deviation score is 2 (3-1=2) for this question.

The patient's standard neurological motor strength index was 2/5 on the day of the interview, coinciding with an impairment score of 2 (Anderson and Tranel, 1989), which indicates mildly defective motor functioning. Comparing this standard neurological motor strength index to the rating of the patient's response on the interview resulted in a deviation score of 1 on section B. The patient complained of motor impairment, such as inability to move his limbs and of the sensation of "dead nerves in his limbs", corresponding to a score of 2 on the awareness interview. The obtained deviation score indicated a minimal awareness of motor impairment. It should be noted that on repeating measures, the most frequent measure of motor index was 2/5.

On the other hand, the patient exhibited complete unawareness of impairment in the function of visuoperception (section C). He reported having no problems in his sight. Comparing the neuropsychological evaluation (a score1/3 indicating maximum impairment) to the rating of the patient's response on the interview (3/3 indicating denial of impairment in visual perception) resulted in a deviation score of 2 in this area. Hence the patient was unaware of his visual neglect. This result also indicated his unawareness of hemianopia.

The patient reported having no trouble at all in his thinking (intellect, section D). The patient obtained a scaled score of 7 on the vocabulary subtest of the WAIS. This scaled score is 1 SD unit below the mean and corresponds to an estimated Full IQ that is 1 SD unit below the standard mean. In a comparison of the patient's answers and his actual neurological profile, he obtained a deviation score of 1 on this section. Such a score indicates somehow awareness of intellectual abilities.

Concerning his awareness of speech and language (section E), the patient complained about a difficulty in articulating words "heaviness in tongue". Upon neurological evaluation, he was given a score of 3 on a 3-point scale because he showed no language problems. On the other hand, he obtained a score of 2 on the interview because he described a mild speech or language problem. The result was a deviation score of 1, indicating some awareness of damage.

Section F (12) investigated the patient's awareness of the quality of his performance on the DL and TP tests. At the end of the interview the patient affirmed that he performed "well" on both tests, which granted him a score of three on the awareness interview because he indicated that his test performances were normal. According to neuropsychological evaluation of performance on the TP and DL, he obtained a score of 1 on the 3-points scale, indicating maximum impairment. All in all the patient's deviation score on this section is 2.

Tachistoscopic Presentation Follow up

Six months later, the TP was readministered to the patient in order to follow up on the prognosis of visual neglect. In the follow up, both the simple and the complex tasks started with the 150 ms series and finished with the 1000 ms series. The results are shown in table 4.

Table 4

The patient's performance upon follow up on the TP.

	Duration of Display		
HS	150 ms	300 ms	1000 ms
	Simple Task		
Left	11	12	14
Center	6	8	8
Right	21	23	23
	Complex Task		
Left	3	6	9
Center	7	7	8
Right	18	23	23

Note. The values represent the number of correctly identified targets. HS=Hemispace.

The simple task

The patient's scores obtained in the follow up were compared to the original results (tables 1) of the control participant. The patient's performance in the right visual hemispace was similar to the control participant's performance during the three series.

The patient identified all of 23 targets during the 300 and the 1000 ms series and 21 targets in the 150 ms series.

In the left visual hemispace, the patient identified 11, 12, and 14 targets out of 23 during the 150, 300, and 1000 ms respectively. Furthermore, the patient noticed all the 8 stimuli displayed in the center of the screen during the 1000 ms and the 300 ms, and 6 of those 8 stimuli during the 150 ms series.

The complex task

In comparing the patient's follow up performance with the control participant original (tables 2) performance, we find the same performance for both participants in the central visual field. Both participants performed similarly in the right visual hemispace, with a superior performance by the patient. The control participant distinguished 17, 20, and 23 of 23 compared to 18, 23, and 23 of 23 by the patient during the 150, 300, and 1000 ms respectively.

Although the patient's performance showed amelioration of visual neglect on the three series upon follow up, still, his performance in the left visual hemispace for the complex task was poorer than that of the control participant. Of 23 stimuli he identified 3, 6, and 9 respectively in the 150 ms, 300 ms, and 1000 ms.

CHAPTER IV

Discussion

The present findings are based on a case study. Surely a larger sample would have given more weight to the results. The study was limited to one case for the following reasons. First, it is not frequent to find a patient with neglect; in addition, neglect studies are usually done longitudinally, which is beyond the time limits given for the current study. Second, studies of neglect have shown that individual differences between patients are considerable. Walker (1995) stated:

> It is argued that as neglect is not a unitary disorder it is best studied using single cases designs and that group studies may well be inappropriate unless the dissociations in each patient's performance are examined in detail. (p. 371)

In the current study, I investigated the co-occurrence of visual and auditory neglect by examining the presence of left auditory neglect in a patient with left visual neglect following a right hemisphere stroke. For this purpose the Tachistoscopic Presentation and the Dichotic Listening techniques were used. The present findings supported a supramodal neglect syndrome and the hypoarousal model proposed by Heilman and his coworkers. The results of the present case study may be summarized as follows: (a) the patient (T. A.) has a right middle cerebral artery (MCA) infarction involving the frontal, temporal and parietal lobes and the inferior parietal lobule; (b) left visual neglect; (c) left auditory neglect; (d) anosognosia for stroke, visual and auditory neglect; and (e) left upper hemispace hemianopia and left hemianesthesia (assessed neurologically).

Based on the results from the first session of the Tachistoscopic Presentation, the conclusion may be drawn that T. A. exhibited severe visual neglect in his left visual hemispace. He did not identify any target stimulus in the left hemispace of the screen during any of the trials on both the simple and the complex tasks. Similarly, the data of the Dichotic Listening obtained for the non-forced, the forced-right, and the forced-left conditions indicated, all in all, that T. A. performed more poorly than the control participant on both ears but especially in the left ear. In fact, on each of the three listening conditions, T. A. correctly reported far fewer syllables from his left ear compared to those reported by the control participant. The latter finding indicated the presence of auditory neglect in T. A.'s left auditory hemispace. When comparing the scores of the two ears for the same participant, it was found that T. A. correctly reported fewer syllables from his left ear compared to those reported from his right ear. In addition, the difference between the scores of the two ears indicated consistently (for the three conditions) a greater discrepancy between the auditory scores on the part of the patient.

Based on the above findings, the results of the Tachistoscopic Presentation and the Dichotic Listening indicated an inattention to both visual and auditory stimuli presented in the left hemispace. This suggested a co-occurrence of visual and auditory neglect.

As mentioned earlier, the results of Storrie-Baker et al.(1997) and the findings of Vallar and his coworkers (Vallar et al., 1993) on vestibular stimulation (VS) were in support of a supramodal hypothesis of neglect. The effect of VS was in temporarily alleviating several forms of neglect. VS of the left ear produced right hemisphere stimulation and leftward bias. Also, the ocular movement towards the left led to temporal remission of tactile neglect, left USN, and anosognosia for left hemiplegia. In line with what was mentioned earlier, the improvements of neglect symptoms showed right asymmetry, hence reflecting a perceptual component of neglect (Vallar et al., 1993). These observations of the effect of VS were interpreted in terms of two theoretical frameworks. Both of the theories imply a multimodal and perceptual model of neglect, where the right hemisphere plays a major role and where the attention and integration of information in the contralateral hemispace is affected.

One of the theoretical frameworks within which the effect of VS was interpreted was proposed by Vallar et al. (1993). According to this framework, both the contralateral and the ipsilateral hemispaces are neurally represented in each of the hemispheres, but the ipsilateral hemispace is represented to a lesser degree. Hence, the ipsilateral gradient is steeper in the left hemisphere compared to the right hemisphere. This suggestion explains the greater contralateral deficit, that is, the severe left visual neglect produced by CVA in the right hemisphere. Similarly, the neural representation of the ipsilateral (left) side of the body is minor in the left hemisphere compared with the right hemisphere representation of the ipsilateral right side. It follows that the range of symptoms displayed by the sampled patients (i.e., tactile neglect, left USN and anosognosia for left hemiplegia) is related to a defective representation of the contralateral half of egocentric space and of the patient's body. Correspondingly, Vallar et al. stated:

> These positive and negative effects of unilateral sensory stimulation on manifestations of hemineglect may be explained by assuming that the core deficit

> is the lack of the normal correspondence between different levels of representation of extrapersonal space and body, due to the ipsilateral displacement of the perceptual component .... An appropriate vestibular stimulation (cold water in the left ear, warm water in the right) modifies the pattern of sensory input on which the internal egocentric representation of the body is constructed. This, in turn, leads to a temporary displacement of the egocentric representation towards the side contralateral to the lesion. (pp. 83-84)

The attention-arousal adopted by Storrie-Baker et al. (1997) to interpret the effect of VS is the other theoretical framework; it was proposed by Heilman (1979), Heilman et al. (1987), and Heilman et al. (1992). Within their theory of brain asymmetry (described in detail earlier), they proposed that, in right-handed people, right hemisphere mechanisms subserve the whole egocentric space while the left hemisphere is concerned only with the right contralateral hemispace. In addition, Heilman and his coworkers proposed a left-right asymmetry in the setting and maintaining of arousal, where the right hemisphere plays the major role. It follows that damage in the right hemisphere leads to the observed multimodal symptomatolgy and ipsilateral manifestation of neglect, that is, RHD affects processing of information presented in both hemispaces (contralateral and ipsilateral). Still within the attention-arousal framework, VS of the left ear temporarily ameliorates the multiple forms of neglect by temporarily activating the hypoaroused right hemisphere, a postulation that was confirmed in the study of Storrie-Baker et al. (1997). In addition, an increase in the right hemisphere arousal level following VS leads to an increase in the attention capacity (Storrie-Baker et al., 1997).

A striking analogy can be found between the present case study and the one presented by Storrie -Baker et al. (1997). To compare the site of lesions involved, in both cases the right hemisphere stroke is localized in the middle cerebral artery infarction, involving the frontal, parietal and temporal lobes. In addition, although the symptoms exhibited by both cases varied in severity, they were similar. Storrie-Baker's patient had left hemiplegia, left homonymous hemianopia, left hemianesthesia, and severe visual neglect (she was not tested for auditory neglect). In addition, she was anosognosic for the first 2 days for her stroke. Likewise, besides left auditory and visual neglect, and upon neurological examination, T. A. exhibited more than one form of neglect, that is, left asomatognosia, left astereognosia, and left hemianesthesia. As mentioned earlier, Storrie-Baker's study confirmed the attention-arousal theory. The similarities between the two cases such as the multiple neglect syndromes suggest that the present findings confirm the attention arousal model proposed by Heilman and his coworkers.

Furthermore, interesting results emerge on examining the data obtained for the visual and auditory performances in the right hemispace of the participants. Although throughout the series of the first session of the TP test the performances of both the control participant and T. A. were somewhat similar in the right (ipsilateral) visual hemispace, T. A.'s performance was poorer. The number of targets that T. A. identified in his right visual hemispace reflected also the presence of inattention in the ipsilateral hemispace. Comparable results were observed on the DL test. Both participants reported correctly more items from the right ear on all of the three listening conditions. For the non-forced and the forced-left condition, this can be attributed to the right ear dominance (Kimura; 1965) or interference from the right ear. However, T. A. showed poorer performance from the right ear on all three conditions of the DL. T. A.'s scores indicated inattention to both left (contralateral) and right (ipsilateral) stimuli. However, his left auditory neglect was deeper because he reported a lesser number of correct syllables from the left ear. Ipsilateral inattention might be explained due to low vigilance or a state hypoarousal that follows right hemisphere lesions. Again, these results might be explained within the attention-arousal model of Heilman and colleagues. According to Heilman et al. (1992), besides being inattentive to contralateral stimuli, patients with unilateral neglect often also show inattention, although less severe, to ipsilateral stimuli. Galvanic skin response and EEG power spectrum recording indicated reduced arousal, as demonstrated by low skin conductance response even to the electric stimuli presented to the ipsilateral hand.

There is also some other pathological evidence pointing in the same direction. For example, Walker (1995) cited that Robertson et al. (1994) found that patients with visual neglect fail to scan the right side of the page adequately, which might lead to right-sided omissions of stimuli. They explained this observation as being due to low levels of vigilance in such patients. De Renzi et al. (1989) cited Weintraub and Mesulam (1987), who found that when single stimuli were flashed in different positions of the right visual field, those stimuli located in the left of the right visual field were responded to more slowly by right parietal patients. Flashing of stimuli leads to avoidance of rightward visual scanning, which brings parts of the right visual field into the patient's left visual field.

In addition, although the results of De Renzi et al. (1989) were at variance with the multimodal hypothesis of USN, some of those results were similar to those obtained in the present study. On the one hand, auditory neglect was not present in nine of the patients showing visual neglect, and two of the nine patients with auditory neglect did not show any visual neglect. However, it should be noted that the patients were required to detect the interruptions that occurred in a sound delivered through earphones. The sounds were delivered either monaurally or binaurally, and during both conditions the interruptions occurred only in one ear; in contrast, in the Dichotic Listening technique used in the present study, the stimuli were constantly given binaurally. On the other hand, the clinical findings of De Renzi et al. showed that five of the nine patients with RHD having auditory neglect also failed to detect interruptions in the ipsilateral (right) ear, though never with the same severity as in the contralateral ear. This latter finding is in line with the present findings. Among those five patients, four showed visual neglect. Furthermore, this finding occurred only in patients with RHD and with contralateral auditory neglect. Accordingly, De Renzi et al. assumed that in these patients, right neglect depended on right hemisphere damage and reflected the unique property of this hemisphere to also exert attentional control on the ipsilateral space.

It follows that the right auditory and visual omissions found in the present study point to a right hemisphere contribution in the deployment of attention not only to the contralateral but also to the ipsilateral space. It is important to mention that omissions in the right hemispace occurred with less frequency than omissions in the left hemispace.

A symptom often found to be associated with neglect is anosognosia. Hence, it was important to examine for its presence in T. A. my major purpose was to investigate awareness of USN and motor impairment. The overall awareness index obtained by T. A. on the awareness interview was 9 over 12. This score indicates that T. A. was relatively unaware of the nature of his illness and some of its implication. The obtained corresponding deviation score indicated a minimal awareness of motor impairment. On the other hand, T. A. reported complete unawareness of his visual neglect, which also indicated his unawareness of hemianopia.

First, concerning the patient's awareness of cognitive impairment, T. A. reported having no trouble at all in his thinking (intellect), which indicated that he was in some way aware of his intellectual abilities. T. A. obtained an estimated Full IQ score of 1 SD unit below the standard mean. This score doesn't imply severe cognitive impairment in the area of intellect, taking into consideration the patient's level of education and his being sedated at testing. Also verbal expression of abstract terms depends on the person's richness of vocabulary, which in turn, is related to the educational level.

Second, the awareness interview also reflected T. A.'s inability to accurately judge his performance on the neuropsychological tests. In fact, at the end of the interview T. A. affirmed that he performed "well" on both the TP and DL tests, which reflected his unawareness of his hemispatial neglect, both visual and auditory. In fact, one month following the stroke and with training at home by his sister, T. A. was walking almost independently, and he was able to use his left hand, but he had to be reminded of it constantly and sometimes even forced to exercise it. Six months following the stroke, he had become functionally independent, but he still was not allowed by his physician to drive or work, especially since his job as a cook requires handling sharp tools. Despite the physician's restrictions, he sometimes drove his car. It might be suggested here that anosognosia might be a compensatory mechanism for the deficiencies he developed. According to Kinsbourne (1987), the reality of deficient performance is excluded from attention and an illusion of competent performance persists. Such a release of evaluation of performance in terms of instrumental success may be due to parietal release from temporal control. In addition, Kinsbourne stated:

> Though quite capable of observing the cues that would inform him that his performance is defective, the patient fails to relate this information to the performance. Given that he feels he is competent he asserts this feeling in words and deed. (p. 80)

Third, my findings on the Awareness Interview might indicate a dissociation between anosognosia for motor defect and anosognosia for visual field defect (visual neglect and hemianopia). Anderson and Tranel (1989) evaluated awareness of cognitive and motor impairment in 100 patients with cerebral infarction, dementia or head trauma. As for patients with hemiparesis, they were all unaware of cognitive impairments; however, some of these patients fully acknowledged motor defects. A major component of awareness of hemiparesis is that the structures necessary for perception of an impaired function, are themselves disrupted (Damasio & Anderson, 1989; as cited in Anderson & Tranel, 1989).

Similarly, anosognosia for motor and visual field defects (hemianopia) were found to be double dissociated from personal and extrapersonal neglect (Bisiach et al., 1986). They found that the patients who were completely inattentive to the left side might fully appreciate their motor impairment. In addition, anosognosia for hemianopia was more frequent than that for motor impairment, but the latter was more associated with unilateral neglect. They also reported that among 10 patients examined for the occurrence of both forms of anosognosia, four patients showing severe anosognosia for hemianopia had minimal anosognosia for hemiplegia. Accordingly, the authors proposed the hypothesis that anosognosia can be divided into function-specific forms in which lack of awareness of an impairment in one function reveals a disorder at the highest level of that function. This was opposed to previous theories explaining anosognosia in terms of a repression of an ego-threatening reality within a few hours of the onset of the brain damage (Weinstein, & Kahn, 1955; as cited in Bisiach et al., 1986), or in terms of hypoarousal following RHD (Heilman), or in terms of general confusion (Mesulam).

Our findings are rather more likely to be in line with those of Cutting (1978). Cutting investigated anosognosia in100 acute hemiplegia cases. He based his assessment on clinical observation and found that 87% of his left hemiplegic patients exhibited anosognosia versus 30-40% in other studies. Comparing his findings to those of others he found that the longer the mean interval between assessment for anosognosia and the onset of the stroke, the less likely are hemiplegic patients to exhibit anosognosia. This led Cutting to suggest that the development of anosognosia might be related to recency of the CVA. Findings in which chronic hemiplegic patients rarely exhibit anosognosia (Gilliat & Pratt, 1952; as cited in Cutting, 1978) supported this suggestion. Returning to this case study, according to the medical staff informal report, T. A. was anosognostic for the hemiparesis in his arm and leg on the first days after admission until he was told that his hand and leg were weak. T. A. was interviewed on the 7th day poststroke, so when he was asked questions about his hemiparesis, he showed some awareness of the weakness in his left hand and foot.

The most fundamental criteria of the anosognostic condition were, according to Cutting (1978), the failure to integrate information from one side of the body. He explained his observed results in terms of two approaches. One of the approaches he discussed was that anosognosia is a form of agnosia. He based his comparison on a conception of visual agnosia by Taylor and Warrington (1971), which considers anosognosia as a component of two forms: apperceptive and associational. Those patients showing no grasp of the morbid change in the limbs were assumed to show "apperceptive anosognosia". On the other hand, those patients who grasped the morbid change but were not able to judge the cause of hospitalization showed disturbance in association by a faulty choice of linguistic terms to express their experience.

The other approach discussed by Cutting (1978) was the "neglect" concept of anosognosia. Basing his comparison on an earlier definition of neglect as a central system (Denny-Brown et al., 1952), Cutting stated that neglect is " a fundamental characteristic of parietal lobe disease of either hemisphere, and which consists of a tendency to extinguish one member of a stimulus pair and to lose insight into perceptual processes"(p.553-554). Cutting claimed that the symptomatology of his patients was similar to this neglect concept of anosognostic behavior and to the findings of Heilman and Valenstein (1972a) (discussed earlier). In fact, his patients' conditions were transient, accompanied by apathy, and the patients showed defect in both the visual and kinesthetic source of information. Also, they showed visual neglect as a trend. According to the neglect definition of anosognosia, Cutting argued that anosognostic patients can be placed along a spectrum with, at one end, those patients with severe anosognosia, exhibiting explicit denial of illness, and at the other end those patients who grasp the morbid change but lack the capacity to make an accurate judgement of the weakness and of the cause of hospitalization due to disruption in central analysis. Comparatively, T. A. was able to recognize the morbid change in his limbs; however, his reports on the awareness interview indicated that he failed to make an accurate judgement of this weakness, and that he was unaware of the exact nature of his illness and of its implications. For example, he described a heaviness in his limbs- a sensation of "dead nerves in his limbs"- and mentioned headache as the primary reason for hospitalization (never stroke), and he claimed that he was able to live independently. On the other hand, T. A. was upset by his mood change, that is, his irritability and nervousness (he wanted to get out of the hospital). He was also apathetic about external events. Similarly, Heilman (1979) described patients with neglect as being apathetic about events taking place in their environment and not related to their illness.

All in all, as in Denny-Brown's definition of neglect cited above, besides damage to the parietal lobe, T. A. showed more than one form of neglect: auditory and visual neglect, and tactile extinction. Hence, the explanation of the present results supports rather a central system that is affected or a neglect concept of anosognosia.

Other evidence on anosognosia emphasizes that the damage site is in the parietal lobe. In a study on 97 patients with RHD, Bisiach et al. (1986) found a correlation between the anatomical site of lesion overlap and anosognosia for motor impairment and anosognosia for visual hemispace defect. In fact, in two-thirds of the patients, CT scan showed the lesion to be in the inferior-posterior parietal region. According to Bisiach et al., earlier findings of the literature (Critchley, 1953) reported an association between parietal damage and anosognosia. This suggested a major role of the inferior-posterior parietal damage in anosognosia (Bisiach et al., 1986).

This leads us to examine the site of lesion involved in T. A. The results of the MRI confirmed frontal, parietal, and temporal lesions of the right hemisphere, extending to the inferior parietal lobule. Similarly, in the studies we reviewed on audiovisual neglect, the inferior parietal lobule was found to be the site of lesion involved. The right inferior parietal lobule was the location of the lesion commonly involved in six of the seven cases presented in the series of studies investigating audiovisual neglect by Soroker et al. (1995a; 1995b) and Soroker et al. (1997). In addition, in three of the patients the frontal, temporal and parietal lobes were involved (Soroker et al. 1995b). Furthermore, Bisiach et al. (1984) investigated auditory lateralization in patients with RHD. Their results showed that among the patients who showed systematic error of lateralization to the right, the region of lesion overlap was surrounding the posterior two-thirds of the sylvian fissure. Moreover, this lesion tended to be larger in those cases that manifested also left visual neglect. They further noted that when left visual neglect is present the inferior parietal lobule appears to be impaired. They also suggested:

> It may be the case that lesions affecting the inferior parietal lobule produce a severe distortion of the inner representation of egocentric space. Conversely, when this region is spared a minor distortion occurs, yielding more subtle disturbances, such as disorders of auditory lateralization. (Bisiach et al, 1984, pp. 50-51).

Moreover, several researchers such as Heilman et al. (1992), Mesulam (1981), and Posner et al. (1984), whose theories we discussed in details earlier, have insisted on the importance of the inferior parietal lobule in the attention mechanism. All the three theories imply a central multimodal mechanism of information processing.

As mentioned earlier, within the theory of asymmetry of Heilman et al. (1989) and Heilman et al. (1992), the parietal lobe plays an important role in the attention-arousal in normal individuals. The inferior parietal lobule appears to be a polymodal secondary association area. The primary sensory areas of audition, vision, and somesthesis project to their respective unimodal association areas, and each association area, in turn, projects to the inferior parietal lobule (in addition to the prefrontal cortex, superior temporal sulcus) (Heilman et al., 1987; Heilman et al., 1992). Also, research results reported in Heilman et al. (1992) indicated that when sites such as the superior temporal and the inferior parietal lobe are ablated, there is EEG evidence of ipsilateral hypoarousal. Accordingly, the lesion of the inferior parietal lobule found in T. A. might be associated with a general state of hypoarousal, as indicated by the multimodality of symptoms exhibited by T. A., that is, visual and auditory neglect, anosognosia, somatesthetic neglect, and ipsilateral omission.

The results of the follow up on the prognosis of visual neglect showed a clear amelioration of neglect in the left visual hemispace and, especially, in the central visual field, on both the simple and the complex tasks. In addition, T. A.'s performance in the right visual hemispace was similar to the control participant's performance during the three exposure series, on both tasks. These results indicated also amelioration of his attention in the right visual hemispace.

Although T. A.'s performance showed amelioration of visual neglect on the three series upon follow up, still, his performance in the left visual hemispace, especially on the complex task, was poorer than that of the control participant. It follows from this observation that the neglect was still manifesting itself in the left hemispace. It is worthwhile noting that whereas initially patients with neglect ignore stimuli presented on the contralesional side, upon improvement, they become able to detect and lateralize stimuli present on this side (Heilman et al, 1992). However, at the later phase, visual neglect, especially, manifests itself as a form of extinction upon bilateral simultaneous stimulation (BSS) but not upon a single stimulation, as when the stimulus is displayed in the center. The latter suggestion might explain why the amelioration of neglect was better in the middle than in the left hemispace. It was observed that neglect is manifested intermittently in the left visual hemispace on some of the trials, especially during BSS. The poorer performance shown by T. A. in the left hemispace might not be attributed to distractibility since T. A. showed normal performance in the right visual hemispace. So, this asymmetry in performance might be indicative of the perceptual aspect of neglect, especially since neglect is manifested intermittently in the left visual hemispace on some of the trials of the follow up.

Within the Heilman and coworkers framework, it can be suggested that USN patients can be placed along a spectrum, with at one end those patients who manifest USN to one stimulus presented in the contralateral hemispace. At the other end of the spectrum, neglect is manifested in its minor forms, that is, upon BSS. It should be noted that, based on the neurologist bedside examination effectuated a few days after the onset of the stroke, T. A. similarly showed neglect of auditory and visual stimuli presented unilaterally (finger snapping and finger movement) in the left hemispace. However, on some of the trials upon follow up, Tachistoscopic Presentation revealed inattention to left stimuli during a bilateral simultaneous presentation of stimuli.

Another observation worth discussing is that upon both TP testing sessions (bedside and follow up), T. A.'s manifestation of visual neglect was deeper in the complex than in the simple task, in which a higher number of omission error was observed in the left visual hemispace. Heilman et al. (1986) proposed that by detecting the target from foils, as is the case here, leads to an increase in hemispatial neglect; this task requires closer scrutiny of details and hence a focused attention.

Besides the interpretation of the major findings of this study mentioned so far, there are some observations that are worth discussing. One of these is the observation of the T. A.'s performance in the center of the screen on the TP tasks. In fact, compared to the control participant, the patient reported seeing only a few and, sometimes none, of the target stimuli displayed in the center of the screen during each of the three series of the simple and the complex tasks respectively. This finding also reflected the presence of severe visual neglect in T. A.'s central visual field. T. A.'s central visual field corresponds also to the extreme left of his right visual hemispace. Within Kinsbourne's (1987) mutual-inhibitory model, one of the aspects by which attentional bias is manifested in unilateral neglect is an exaggerated attention to the extreme right of a display, irrespective of its absolute location, as well as an impaired attention to the left. He argues that, based on his findings on patients with lateralized lesions in the posterior hemisphere and tested by means of the tachistoscopic display of letter groups, these gradients of attention were demonstrable within as well as between half fields. In addition, within the half field, the accuracy of identification is highest in the extreme ipsilesional location (Kinsbourne, 1987). Also, according to Posner et al. (1984), patients with neglect are strikingly slow in shifting attention contralesionally, even when they initiate the shift within the intact visual half field and direct it to a more centrally located target that is still within the same intact visual half field. The observations of the patient's performance in the middle visual field are in accord with Kinsbourne's findings that may support a lateral difference within the same half field and the gradient of attention theory. This suggestion, as mentioned earlier, opposes the dichotomous half space model. It might be suggested that the gradient pattern does not lead to rejection of the Attention-arousal model. Within the theory of brain asymmetry of Heilman, the intact left hemisphere attends to the right, and in case of severe USN, the attention becomes more shifted to the extreme right and decreases as it shifts closer to the left of the right hemispace.

Some general suggestions might be relevant here regarding the overall pattern of the results of the DL .T. A.'s inability to read the CV syllables correctly might have interfered with correctly recognizing the sounds. In addition, the somewhat poor performance of control participant might be due to cross-cultural linguistic differences, which interfered with sound differentiation. Although the DL test was designed using CV syllables in order to overcome linguistic barriers, it is important to note that the consonant P is not a part of the Arabic alphabet. In addition, the participants, due to their limited education, do not speak (read or understand) any other language. This suggestion was supported by the finding that both participants never reported correctly the homonym 'pa' in any of the three conditions. Also, they both incorrectly reported 'pa' as 'ka'. Such variance is to be expected since making sense of the speech sounds of an unfamiliar language accurately and rapidly requires a high degree of skill not available to everyone with different linguistic experience. Here, it might be suggested that there is a need to design a new Dichotic Listening version with CV syllables from the Arabic language.

Conclusion

The aim of this research was to present one more case study in support of the supramodal hypothesis, using updated versions of the Tachistoscopic Presentation and the Dichotic Listening techniques. Both techniques have proven to be sensitive in detecting hemispatial neglect. The results confirmed my prediction that a patient with left visual neglect following RHD would also show evidence of auditory neglect to the contralateral (left) hemispace. Hence, the present findings support a multimodal theory of USN within an attention- arousal theory of USN. Within this framework, a lesion in the posterior parietal lobule, which is the most frequent anatomical correlate of neglect in humans and which is an area involved in T. A., tends to block the multiple unimodal inputs converging on it. Such a hypothesis would imply that neglect must necessarily involve a multitude of sensory inputs, independent of the modality through which they are transmitted. In fact, T. A. exhibited a wide range of neglect phenomena, namely anosognosia, left somesthetic neglect and to a lesser extent a multimodal (auditory and visual) omission of stimuli presented in the right ipsilateral hemispace.

The present study leads to the following recommendations, which might be used for future research. First, it is important to design a Dichotic Listening version for Arabic native speakers. Second, testing for auditory and other forms of neglect have to be considered during clinical assessment of patients with stroke who exhibit visual neglect. Finally, the present research cannot claim the ability to resolve the issues of unimodality versus supramodality, nor hypoarousal versus disinhibition. However, contribution toward elucidating the issues of unimodality or supramodality and of the pathophysiological mechanism underlying USN are essential steps toward more accurate diagnosis, prognosis and finding the appropriate rehabilitation method for stroke patients with USN.

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Appendix

The Awareness Interview

Section A. Awareness of the reason for hospitalization.

1- Why are you in the hospital? What is wrong with you? (Did you have a stroke?)
SCORING
3 Patient explicitly denies the primary reason for hospitalization.
2 Patient admits to, but does not initially state, the primary reason for hospitalization.
1 Patient describes the primary reason for hospitalization.

2-Does your illness has any effect on your everyday life? In what way?
SCORING
3 Patient explicitly denies that the illness had any effect on his everyday life.
2 Patient admits to, but does not initially state, that the illness had any effect on his everyday life.
1 Patient describes accurately the effect of the illness on his everyday life.

3- Are you any different now compared to what you were like before your illness? In what way?
SCORING
3 Patient explicitly denies that any notable changes from the normal state.
2 Patient admits to, but does not initially state, the changes from the normal state.
1 Patient describes accurately the changes due to the illness.

4- Are you ability to live independently?
SCORING
3 Patient indicates that there will be no problem returning to normal activities.
2 Patient indicates that there will be difficulty returning to normal activities.
1 Patient indicates that there will be difficulty returning to normal activities in the next several weeks.

5- Do you feel that anything about you, or your abilities has changed?
SCORING
3 Patient explicitly denies the thing(s) about him, or his abilities that have changed.
2 Patient admits to, but does not initially state, the thing(s) about him, or his abilities that have changed.
1 Patient describes accurately those things about him, or his abilities that have changed.

6- What do you see as your problems, if any, resulting from your illness?
SCORING
3 Patient explicitly denies that the illness produced any notable problem.
2 Patient admits to, but does not initially state, the problems due to the illness.
1 Patient describes accurately the effect of the problem due to the illness.

7- What is the main thing you need to work or would like to get better?
SCORING
3 Patient explicitly denies that there is something wrong with him.
2 Patient admits to, but does not initially state, the existence of the impairment that he needs to get better.
1 Patient describes accurately the impairment(s) he would like to get better.

<u>Section B. Awareness of motor impairments.</u>

Question the patient regarding movement and impairment: paying particular attention to deficits noted in neurological evaluation.

8- Is there anything wrong with your arm or leg?
SCORING
3 Patient denies any motor impairment.
2 Patient describes a minimal impairment of motor function.
1. Patient complains of a significant motor impairment.

<u>Posttests Sections</u>

Section C. Awareness of visual perceptual problems.

11-Are you having trouble with your vision?
SCORING
3. Patient denies any problems with visual perception.
2. Patient describes mild problems with visual perception.
1. Patient complains of a significant visual perceptual impairment.

Section C. Awareness of impairments of intellect or " thinking ability".

12- Are you thinking normally as you usually do?
SCORING
3. Patient describes clear thinking without any notable changes from the normal state.
2. Patient notes a mild change in one or several aspects of thinking (e.g., decreased ability to concentrate, solve problems, or respond to situations).
1. Patient complains of major difficulty or changes in thinking.

Section E. Awareness of speech or language problems.
13- Has your speech been affected? Do you have any difficulty understanding what other people say?

SCORING

3 Patient denies any speech or language problems.

2 Patient describes mild speech of language problems (e.g., word finding problems, slurring).

1 Patient complains of impaired comprehension, aphasic speech, or severe dysarthria.

Section F. Awareness of quality of test performance and ability to return to normal activities.
14- How do you think you did on these tests?

SCORING

3 Patient indicates that test performances were normal.

2 Patient indicates that test performance were somehow defective.

1 Patient indicates that test performance was defective.

Glossary

Akinesia (also Motor Neglect): Delay or inability to initiate goal-directed movements to the affected (contralateral) limb's space. This is illustrated by the patient's failure to respond to ipsilateral stimuli with the contralateral arm.

Anosodiaphoria: Indifference about an illness.

Anosognosia: Failure on the part of the patient to acknowledge acquired motor, visual and cognitive deficits in response to explicit questioning.

Aphasia: Partial or total loss of the use of language as a result of brain damage, characterized by an inability to use and/or comprehend language.

Apraxia: Partial or complete loss of the ability to perform purposive movements. The term is restricted to conditions resulting from cortical lesions in which there is no paralysis or loss of sensory functions.

Arousal: A physiologic state that increases neuronal excitability and thereby prepares the organism for sensory and motor processing.

Asomatognosia (also Personal Neglect): Failure to recognize one's own limbs that are contralateral to the lesion, complaining, for instance, that it is someone else's arm or leg.

Astereognosia: Partial or complete inability to recognize objects by touch.

Attentional Blink: A measure of human ability to allocate attention over time (temporal attention).

Auditory Neglect: Neglect or incorrect orientation to unilateral auditory stimuli.

Braistem: The lower part of the brain, between the forebrain and spinal cord, which activates the cortex and makes perception and consciousness possible; it includes the midbrain, pons, medulla, and cerebellum.

BSS: Bilateral Simultaneous Stimulation.

Contralateral: Pertaining to the opposite side.

Detection Task: A task where participants are warned beforehand that a stimulus will be presented and are instructed to report the stimulus when or where they see or hear it.

Dysgraphia: Inability to write or express properly or to express oneself through writing. The term is reserved for cases brought about through brain damage.

Dyslexia: Difficulties learning to read. It may follow damage to the left cerebral hemisphere.

Extinction: The failure to respond to visual, auditory, or tactile stimuli in the contralateral field or limb after BSS.

Hemianopia: Blindness in one half of the visual field. It results from a variety of lesions in the optic pathways and can take a variety of forms. Often used qualifiers so that the particular form is noted; e.g. bitemporal = affecting only the temporal half of the visual field of each eye, unilateral = affecting only one eye.

Hemiparesis: Partial paralysis of one part of the body of organic origin.

Hemispace: It can be defined within either egocentric (body-referenced) or allocentric (object-referenced) coordinate systems. Within the egocentric frame of reference, left is defined with respect to the viewer's own body coordinate. Thus, left is the person's left visual field with respect to retinal coordinates. It can be the left of the body midline, when taking the person's own body trunk as reference, or it can be the left of the body midline with respect to the viewer's head.

Hemispheric Asymmetries: Asymmetric specialization of psychological functions in the cerebral hemisphere.

Hypokinesia: A difficulty in moving the head or eyes or limb in order to explore the hemispace contralateral to a hemispheric lesion. In this case the patient fails to respond to contralateral stimuli with the ipsilateral arm.

Ipsilateral: Pertaining to the same side.

Ischemia: Reduced blood flow to a part of the body.

Lateralities: Asymmetric specialization of the brain and body; hemispheric asymmetries are an example of one type of laterality.

Lateralization: The process by which different functions and processes become associated with one or the other side of the brain.

LHD: Left hemisphere damage.

Object-Based Neglect: A tendency to omit the contralesional side, or parts of the contralesional side, of an individual object regardless of its spatial (ipsilateral or contralateral) position. In these cases neglect occurs in an object-referenced coordinate system.

RHD: Right hemisphere neglect.

Somatoesthetic or Tactile Neglect: Reflects the inability of patients to detect unseen stimuli either when these are presented on their bodily surface or when they are engaged in a searching task in extrapersonal space.

Spatial- Based Neglect: It is indicated by a tendency to omit stimuli located on the contralesional side of the space. In these cases, space is defined in egocentric.

Stroke: A vascular accident resulting from either the rupture of a vessel or the blocking of blood flow artery.

Unilateral Spatial Neglect (USN) (also Hemispatial Sensory Neglect): A phenomenon characterized by the failure to orient towards, respond to, or report stimuli (e.g., visual, auditory) presented in the contralesional hemispace.

Vestibular Stimulation (VS): It is a procedure of introducing cold water to the ear contralateral or warm water to the ear ipsilateral to the lesion producing a slow phase of nystamus with leftward eye deviation.

Visual Neglect: the absence of awareness to visual stimuli in the field contralateral to a lesion. Sometimes it can be ipsilateral.