Inter-hemispheric interaction in the Split Brain:
Inhibitory and Facilitatory priming.

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Two experiments are reported investigating attentional interactions in two split-brain patients. Subjects were required to categorise a stimulus briefly presented to the right visual field, while ignoring a stimulus presented to the left visual field. Experiment 1 used word stimuli, while Experiment 2 used digits as stimuli. Both inhibitory (negative priming) and facilitatory priming effects were found. Experiment 2 showed that in split-brain patients these effects can be explained in terms of sub-cortical transfer of a simple code representing the category (living or non-living, odd or even) of the unattended LVF stimulus. It is proposed that even in the absence of commissural connections there are rich inter-hemispheric facilitatory and inhibitory attentional interactions, proceeding via sub-cortical pathways.

As the name implies, the split-brain operation involves a radical disconnection between the left and right cerebral hemispheres. The functional consequences of commissurotomy have been studied intensively for several decades now (see Trevarthen, 1990 for review). A great deal of the work on this topic can be characterised as addressing either of two complementary questions: What functions are divided by the operation, and what functions remain undivided following commissurotomy? Naturally, a great deal of interest in the split-brain has revolved around the first of these issues. Commissurotomy has provided neuroscientists with a unique opportunity for studying cognitive specialisation within each hemisphere. However, the aim of the two experiments reported in this paper was to address a question of the latter kind. These experiments involved studying inter-hemispheric attentional interactions, in the absence of cerebral commissures.

Studies recently reported by Lambert (1991,1993) have employed with commissurotomy patients, experimental paradigms commonly used with normal individuals in the study of selective attention. These paradigms involve presenting the subject with two visual stimuli simultaneously. The subject is asked to attend, and respond to one of the stimuli (the target), and to ignore the other stimulus (the distractor). Assessing any effects the distractor has on processing of the target stimulus allows inferences to be made concerning mechanisms of selective attention (see Allport, 1989 and Kinchla, 1992 for reviews), and concerning processing of the distractor item. In Lambert's (1991) study, a single patient (LB) from the California series, operated on by Drs. Vogel and Bogen, was given a task involving presentation of a target word to the right visual field (RVF) and a distractor word to the left visual field (LVF). The latency with which LB categorised the RVF word was influenced by the semantic category (living or non-living) of the ignored, LVF word. Response times were <u>slower</u> when the target and distractor belonged to the

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same category. This finding was interpreted in terms of an inhibitory process operating between encoding of the unattended, LVF item, and the attended RVF item. The result closely resembled that shown by normal subjects who were given an almost identical task (Lambert, Beard and Thompson, 1988). In Lambert's (1993) study, two split-brain patients (LB and AA) participated in a study of 'negative priming', in which they categorised a digit presented to the RVF as odd or even, while ignoring digits presented to the LVF. In the negative priming paradigm performance in a control condition is compared with performance in an experimental condition, in which each target is identical, or related, to the distractor item on the previous trial. In a number of variants of this paradigm, it has been found that response latencies are slower in the negative priming condition, compared to control. Both LB and AA were significantly slower in the negative priming condition, in which each RVF target was identical to the LVF distractor from the previous trial, relative to control.

The common factor in both these studies is that a high level, categorical attribute of the ignored LVF-right hemisphere stimulus influenced processing of the RVF-left hemisphere stimulus. From this it was concluded that even in the absence of commissural connections, there are rich attentional interactions between the cerebral hemispheres. Furthermore, these interactions can involve high level cognitive attributes. Conventional views of the split-brain have tended to emphasise the separateness of the cerebral hemispheres, with respect to complex cognitive information, following commissurotomy. On the one hand, it has long been acknowledged that some functions do remain undivided following commissurotomy. For example those concerned with 'ambient visual function' (Trevarthen and Sperry, 1973), and the processing of emotional information (Sperry, 1985; Sperry, Zaidel and Zaidel, 1977). However, high level cognitive functions have traditionally been seen as divided. The results reported by Lambert (1991,1993) were interpreted as showing, to the contrary, that sub-cortical pathways may mediate attentional interactions concerning complex stimulus attributes.

A second aspect of these findings is that in both cases the effects were inhibitory, in the sense that responses were slower when the target and distractor were related or identical. In the first study (Lambert, 1991) inhibition operated within a trial in a word categorisation task, while in the second study (Lambert, 1993) distractor encoding inhibited target processing on the succeeding trial. In common with Allport (1989) and Lambert et al. (1988) it was suggested that these effects reflect an inhibitory process of selective attention, whereby ignored items are isolated from the control of action. Intactness of these effects following commissurotomy suggested that these inhibitory processes proceed via mid-brain pathways.

Experiment 1

The aim of Experiment 1 was to provide a further test of the hypothesis that sub-cortical pathways may mediate attentional interactions between information processing in the left and right hemispheres, following commissurotomy. The design used was a variant of the negative priming paradigm employed earlier (Lambert, 1993). However, this study made use of three and four letter words as stimuli, rather than digits. A single split-brain patient (LB) was tested. His task was to categorise (as living or non-living) a word briefly flashed to the RVF, while ignoring a word flashed to the LVF. In the Negative Priming Condition, each RVF word was identical to the LVF distractor from the previous trial. In the Control Condition there was no systematic relation between LVF words and RVF words.

Method

Subject:

A single split-brain patient (LB) was tested. LB was 40 years old at the time of testing, and underwent complete section of the corpus callosum, anterior and hippocampal commissures in 1965. Detailed information concerning the surgery and neurological status of LB can be found in Bogen et al. (1988, 1975).

Apparatus:

An IBM compatible personal computer with VGA resolution screen (640x350 pixels) was used for display presentation and timing. A chinrest was used to control viewing distance at approximately 53cms. Eye position was monitored by means of a video camera, mounted on top of the display screen. Timing and display routines were written in Turbo Pascal 6.0.

Stimuli:

Stimuli used in the experiment were 40 three letter nouns, and 80 four letter nouns. They were presented in upper case, in Turbo Pascal Sans Serif Font, Size 2. Half the words referred to something living, and half referred to something non-living. The nouns used were as follows:

3 letter nouns:

ASS, LAD, ELK, KID, HEN, ANT, BEE, DOG, BOY,

MAN, COW, PIG, CAT, PUP, EEL, FOX, RAT, OWL, APE, CUB, ARK, URN, TUB, DOT, COT, PIN, RAG, PIT, PAN, MAT BIN, CAP, NET, GUN, HAT, JET, GEM, RIM, TIN, CAR

4 letter nouns:

BABY, BIRD, FISH, GIRL, KING, WIFE, DEER, BEAR, LION, GOAT, LAMB, WORM, WASP, POET, PONY, WOLF, DUCK, CROW, STAG, DOVE, MULE, TOAD, FLEA, SWAN, MAID, FROG, FOAL, HAWK, PUMA, MONK, BULL, CALF, MARE, GULL, LYNX, FOWL, MOTH, MOLE, BOAR, CRAB, BALL, BOAT, BOOK, SHOE, BOWL, DOOR, FLAG, FORK, GOLD, BIKE, HILL, DISH, PIPE, ROAD, ROCK, SALT, SAND, SEAT, SHIP, STAR, WALL, IRON, CITY, CART, DUST, ROOF, LAMP, CARD, HOSE, DESK, HOOP, ROPE, RAIL, HARP, SHED, COAT, BOOT, HALL, SOAP, CONE

Procedure:

The subject was seated in front of the display screen and informed that on each trial of the experiment two words would appear, one to the right and one to the left of a central fixation cross. He was instructed to maintain fixation on this cross at all times, and to categorise the right hand word as referring to something living or non-living. He was instructed to press the 'n' key on the keyboard if the RVF word referred to something living, and to press the 'b' key if it referred to something non-living. He was informed that the left visual field word was irrelevant, and instructed to ignore it at all times. Direction of gaze was monitored by means of the video camera, positioned above the display screen. LB successfully maintained fixation during testing.

Each trial began with the simultaneous presentation of two words, to LVF and RVF respectively for 100msec. The timing and accuracy of the subject's response was recorded by the computer. The computer produced a warning 'beep' following incorrect responses. The next trial was initiated by pressing the space bar with the thumb. After a delay of 500 ms the next pair of words was presented. A rest period, the duration of which was controlled by the subject, was provided at the end of each block.

The inner edge of each digit was presented approximately 2.3 degrees from the central fixation cross. Individual letters subtended approximately .4 degrees by .7 degrees. Three letter words subtended approximately 1.35 degrees horizontally, while 4 letter words subtended approximately 1.8 degrees horizontally. The central fixation cross subtended approximately .65 deg. by .65 deg.

Design:

Each testing session comprised four blocks of 28 trials. In Control blocks of trials there was no systematic relation between distractor (LVF) words and target (RVF) words. In Negative Priming blocks of trials distractor words on trial n were always identical to target words on trial n+1.

LB participated in two sessions of testing. In the first session of testing he responded with his left hand, and received four blocks of trials with the following arrangement of conditions: Control Trials - Negative Priming Trials - Control Trials- Negative Priming Trials. In the second session he responded with his right hand, and received the following arrangement of conditions: Negative Priming Trials - Control Trials - Negative Priming Trials - Control Trials.

Each of the 112 words was presented once during the first two blocks of trials, and then once more during the second two blocks of trials. A different random sequence of trials, and assignment of words to conditions was used for each session of testing.

RESULTS

Response latencies from the experiment were analysed following the same strategy as that employed in Lambert (1993). That is, median response latencies were calculated for each condition (Negative Priming or Control), at successive positions in the sequence of 28 trials comprising a block. Responses with latencies shorter than 100ms were omitted from this analysis. Trial blocks were divided into fourteen serial positions, where position 1 corresponds to the first and second trials in a block, and position 14 corresponds to the twenty seventh and twenty eighth trials. Latency data from LB, averaged across the last thirteen of these serial positions, for Negative Priming and Control blocks of trials are shown in Table 1 (the first position was omitted,

Table 1, Response Latencies (ms) and Errors(%) in Experiment 1

	Negative Priming	Control	p
Session 1			
Latency (s.d.)	974 (134)	1153 (209)	<.02
Errors	16.1	16.1	n.s.
Session 2			
Latency (s.d.)	1882 (1025)	1537 (525)	n.s.
Errors	25.0	26.8	n.s.

since by definition Negative Priming cannot occur on trial 1). Response latencies in the Negative Priming and Control conditions were compared by means of t tests for matched pairs (using the fourteen serial positions as data points).

Preliminary analysis of the data revealed clear differences across sessions in the pattern of results, both in this experiment and in Experiment 2. Accordingly, data from each session was analysed separately. Response latency and error data are shown in Table 1.

As Table 1 shows, in the first session of testing LB's responses were, on average, 179 msec *faster* in the negative priming condition, relative to control. A t test revealed that this difference was statistically significant, t=2.70, d.f.=12, p<.02 (two tailed). In the second testing session, LB's responses were 345msec slower in the negative priming condition relative to control. However, this difference did not approach significance, t=1.20, d.f.=12, n.s.

Analysis using the chi square test revealed that the accuracy of LB's responses did not differ between the negative priming and control conditions.

Discussion

The pattern of results found in the experiment varied between sessions of testing. In the first session, LB's responses were consistently quicker in the negative priming condition relative to control, while in the second session there was no clear difference between the two conditions. Hence, contrary to prediction LB showed evidence of facilitatory rather than inhibitory priming in this situation.

It has been noted previously that the effects of an ignored distractor on an attended target may be highly labile. In several studies it has been observed that such effects may switch from inhibitory to facilitatory according to a variety of task parameters and individual differences (Allport et al., 1985; Lambert et al., 1988; Tipper, 1991; Tipper and Baylis, 1987; Tipper and Cranston, 1985). For example, in a study with normal individuals Lambert et al. (1988) found that spatial bias in a word categorisation task affected whether ignored distractors exerted inhibitory or facilitatory effects on target processing. Allport et al. (1985) and Tipper and Cranston (1985) both reported that the negative priming effect of a distractor (from trial n), on target processing on trial n+1, reversed to facilitatory priming if attentional selection was not required on trial n+1 (i.e. no distractor was present). The priming effects of ignored distractors have also been reported to vary as a function of age and self reports of cognitive failure in everyday life (Tipper, 1991; Tipper and Baylis, 1987). Using an admittedly very different experimental paradigm, Lambert, Spencer and Hockey (1991) found that the effect of irrelevant peripheral visual cues on attention altered as a function of practice. It is clear from this that subtle changes in strategy and practice can influence the type of attentional effect produced by irrelevant stimuli. In the present study it is not clear which factor is responsible for the differing results that were observed across sessions. One factor that did vary across experimental sessions was the hand used for responding: in the first session LB responded with his left hand, and in the second he responded with the right hand. However, in other experiments (Lambert 1993, Lambert & Naikar 1996, Experiment 2 of this paper) attentional effects have not varied systematically according to response hand. Accordingly, it is not likely that the differing pattern of results across the two sessions is due to the use of different response hands in the two sessions. It is also germane to note that the results of a closely similar experiment carried out with normal individuals (Reference Note 1) also showed a significant priming effect, and contrary to prediction this effect was facilitatory rather than inhibitory. The only difference between the design of the two studies was that in the experiment with normal individuals target words shared the same category as distractors on trial n-1, but were not identical.

Although the results were contrary to prediction, they nevertheless demonstrate an inter-hemispheric interaction of the same general kind as reported earlier (Lambert, 1991,1993). That is, LB's performance in categorising a word presented to the left hemisphere was influenced by the category of an unattended word presented to the right hemisphere. This provides further evidence for the conclusion that even in the absence of cerebral commissures there are rich attentional interactions between information processing in the left and right cerebral hemispheres. Furthermore, these interactions, presumably mediated via mid-brain pathways, can involve transfer of a high level cognitive attribute, such as the semantic category of a word.

Experiment 2

The aim of Experiment 2 was to explore in more detail, the nature of the information transfer underlying these attentional interactions. In Experiment 1 and in Lambert's (1993) study negative priming was observed in a situation in which each RVF target was *identical* to the LVF distractor from the previous trial. Negative priming in this situation could potentially arise from information transfer of two kinds. One possibility is that information about the identity of the digit/word is transferred via sub-cortical pathways. Potentially, this might involve either transfer of low level perceptual information, representing the visual features of each stimulus, or a higher level cognitive code representing the identity of the digit/word might be transferred. A second possibility is that a more elementary code, simply representing the category of the digit or word (odd or even; living or non-living) is transferred. These two possibilities were disentangled in the present study by comparing performance across two different conditions of negative priming. The Identity Condition simply replicated the task described earlier (Lambert, 1993). In the Category Condition each RVF target shared the same category with, but was not identical to the LVF distractor presented on the previous trial. If the information transfer underlying these effects is achieved by transfer of identity information, then negative priming should be observed in the Identity Condition, but not in the Category Condition. If the effects are mediated by transfer of a simple representation of the binary category of each digit, then negative priming should be observed in both conditions.

Method

Subjects:

Two split-brain patients were tested, a 42 year old man (A.A.) and the 40 year old man (L.B.), who participated in Experiment 1. These patients underwent compete section of the corpus callosum, anterior and hippocampal commissures in 1964 and 1965 respectively. Detailed information concerning the surgery and neurological status of these individuals can be found in Bogen et al. (1988, 1975).

Apparatus:

As for Experiment 1.

Stimuli:

Stimuli were the digits 1-9 inclusive. They were presented in Turbo Pascal Sans Serif Font, Size 2.

Procedure:

The procedure was identical to that employed by Lambert (1993). Subjects were seated in front of the display screen and informed that on each trial of the experiment two digits would appear, one to the right and one to the left of a central fixation cross. They were instructed to maintain fixation on this cross at all times, and to categorise the right hand digit as odd or even. Subjects were instructed to press the 'n' key on the keyboard if the RVF digit was even, and to press the 'b' key if it was odd. They were told that the left visual field digit was irrelevant, and instructed to ignore it at all times. Direction of gaze was monitored by means of the video camera, positioned above the display screen. Both patients successfully maintained fixation during testing.

Each trial began with presentation of the two digits, presented simultaneously to LVF and RVF for 150msec. The timing and accuracy of the subject's response was recorded by the computer. The computer produced a warning 'beep' following incorrect responses. Subjects then initiated the next trial by pressing the space bar with their thumb. After a delay of 500 ms the next pair of digits was presented. A rest period, the duration of which was controlled by the subject, was provided at the end of each block.

The inner edge of each digit was presented approximately 1.95 degrees from the central fixation cross. Each digit subtended approximately .43 deg. by .8 deg. The central fixation cross subtended approximately .55 deg. by .55 deg.

<u>Design:</u> The Identity and Category conditions were run in separate sessions of testing. Each testing session comprised four blocks of 30 trials. In <u>Control</u> blocks of trials there was no systematic relation between distractor (LVF) digits and target (RVF) digits. In the Identity Condition Control trial sequences were constrained by a requirement that distractors on trial n were never identical to targets on trial n+1. In the Category Condition, sequences of Control trials were constrained by a requirement that distractors on trial n never shared the same category with targets on Trial n+1. In <u>Negative Priming</u> blocks of trials distractor digits on trial n were always identical to target digits on trial n+1, in the Identity Condition. In the Category Condition distractor digits on trial n shared the same category with target digits on trial n+1, in Negative Priming blocks of trials. An additional constraint operating in all conditions was that within a particular trial the target and distractor digits were never identical.

Within a session experimental blocks of trials were presented either with Order 1: in the order Control Trials - Negative Priming Trials - Negative Priming Trials-Control Trials; or with Order 2: Negative priming - Control - Control - Negative Priming.

<u>Identity Condition</u> LB participated in two sessions. Firstly with Order 1 with the left hand, and then with Order 2 with the right hand. AA participated in a single session of testing, with Order 2 using the left hand.

Category Condition LB participated in three sessions of testing. Firstly, with Order 1 using the right hand, then with Order 2 using the right hand, and finally with Order 2 using the left hand. AA participated in two testing sessions. Firstly, with Order 1 using the left hand, and then with Order 2 using the right hand.

Results

Response latencies from the experiment were analysed following the same strategy as that employed in Lambert (1993) and for Experiment 1. That is, median response latencies were calculated for each condition (Negative Priming or Control), at successive positions in the sequence of 30 trials comprising a block. Preliminary analysis showed that in the second session of the Category Condition AA's performance included a number of excessively long response times, together with one very short (57ms) anticipatory response. In view of this response times shorter than 100ms or longer than 5 seconds were omitted from the data set. This resulted in exclusion of seven response times from AA's second testing session in the Category Condition. No other data were lost. As in the earlier report (Lambert, 1993), a trial block was divided into fifteen serial positions, where position 1 corresponds to the first and second trials in a block, and position 15 corresponds to the twenty ninth and thirtieth trials. Latency data from LB and AA, averaged across the last fourteen of these serial positions, for Negative Priming and Control blocks of trials in the Identity and Category Conditions are shown in Table 2 (the first position was omitted, since by definition Negative Priming cannot occur on trial 1). Response latencies in the Negative Priming and Control conditions were compared by means of t tests for matched pairs (using the fourteen serial positions as data points).

As for Experiment 1, data from each session was analysed separately. Response latency data are shown in Table 2, while error data are shown in Table 3.

Table 2, Response Latencies (ms) in Experiment 2

	Negative Priming	Control	p
CATEGORY CONDITION			
LB Session 1 RT (s.d.)	484 (74)	548 (118)	n.s.
LB Session 2 RT (s.d.)	533 (127)	542 (115)	n.s.
LB Session 3 RT (s.d.)	768 (224)	509 (87)	<.01
AA Session 1 RT (s.d.)	735 (103)	795 (99)	n.s.
AA Session 2 RT (s.d.)	800 (242)	1316 (525)	<.01
IDENTITY CONDITION			
LB Session 1 RT (s.d.)	709 (146)	773 (201)	n.s.
LB Session 2 RT (s.d.)	538 (114)	523 (109)	n.s.
AA RT (s.d.)	766 (123)	698 (75)	n.s.

Category Condition

As Table 2 shows, in the first testing session of the Category Condition, LB's responses were, on average 66ms *faster* on negative priming, compared to control trials. In Session 2, LB's responses were again slightly faster (by 9ms), on negative priming trials, relative to control. However, neither of these differences approached significance, t<1 in both cases. In the third testing session, LB's responses were 259ms slower on Negative Priming relative to Control trials. This difference was clearly significant, t(13)=3.72, p<.01 (two tailed). In this session LB also made significantly more errors in the negative priming condition, compared to control, chi square = 6.853, p<.01 (two tailed).

Table 3, Percent error in Experiment 2

	Negative Priming	Control	p
CATEGORY CONDITION			
LB Session 1	6.7	8.3	n.s.
LB Session 2	6.7	6.7	n.s.
LB Session 3	23.3	5.0	<.01
AA Session 1	-	-	-
AA Session 2	-	-	-
IDENTITY CONDITION			
LB Session 1	11.7	11.7	n.s.
LB Session 2	13.3	10.0	n.s.
AA	-	-	-

Latency data from AA are also shown in Table 2. In the first session, AA's responses were 59msec faster in the negative priming relative to control conditions. This difference did not approach significance. In the second session AA's responses were 516msec faster in the Negative Priming condition, compared to control. This difference was significant, t(13)=3.45, p<.01, (two tailed). Unfortunately, error rates could not be calculated for AA. This was because, despite several reminders, AA tended to shift finger position during the experiment, using the 'm' and 'n' keys, rather than 'n' and 'b'. Since, the instruction was to press the right hand key for even and the left hand key for odd it was impossible to ascertain whether AA was using the 'n' key to indicate an even (n vs. b) or an odd (n vs. m) digit.

Identity Condition

In the Identity Condition AA's responses were slower by 68 msec in negative priming compared to control blocks of trials (766ms vs. 698ms). This compares well with the 62ms effect reported earlier (Lambert, 1993), with exactly the same task. However, in this study, the difference between negative priming and control did not attain significance, $t(13)=1.67$, $p<.20$ (two tailed). In the first session of the Identity Condition LB's responses were 64ms *faster* in the negative priming condition (709ms vs. 773ms). In the second session, LB's latencies were 15ms slower in the negative priming condition (538ms vs. 523ms). However, neither of these differences approached significance, $t<1$ in both cases.

Discussion

The present results show a far more variable pattern of performance than was obtained in the earlier study of negative priming with digits (Lambert, 1993). Indeed, across successive sessions of testing the two patients showed either no clear priming at all (both patients, Identity Condition), inhibitory priming (LB, Category Condition), or *facilitatory* priming (AA, Category condition). As noted when discussing results from Experiment 1, the effects of an ignored distractor on an attended target may be highly labile, and can vary according to both strategic factors and individual differences.

Although the results display a variable pattern, they nevertheless are able to answer the question that was asked of the experiment: i.e. Are inter-hemispheric priming effects in this task mediated by transfer of simple binary information concerning stimulus category, or is more complex information concerning the identity of the distractor transferred sub-cortically? The answer seems clear. Both LB and AA showed significant priming effects (albeit of opposite polarity!) in the condition, where target and distractor shared the same category, but were not identical. If anything, these effects were rather larger than those observed in the identity conditions used both in this experiment, and previously (Lambert, 1993), where target and distractor share both identity and category. It is also of interest to note that for LB the presence of a significant negative priming effect in response latency (Category Condition, Session 3) was accompanied by a significant difference in accuracy between the negative priming and control conditions. This mirrors the pattern of the Lambert (1993) study, in which both latency and accuracy effects were observed. It is clear from the present results that a categorical relationship between target and distractor stimuli is sufficient for priming effects to occur. It follows that the effects may be mediated by transfer of a simple binary code representing the category of the object, rather than by transfer of a more complex representation encoding object identity.

This is a valuable finding, since results from earlier studies (Lambert, 1991,1993) were interpreted in terms of inter-hemispheric transfer of complex, semantic information (see Lambert, 1991 pp.945-947). The present results suggest that this conclusion requires an important rider. While sub-cortical pathways can indeed mediate inter-hemispheric interaction with respect to semantic attributes, the transfer mechanism underlying this may be extremely simple, involving transfer of an elementary binary code.

The present finding is also consistent with other studies of the ability to integrate information inter-hemispherically in the split-brain. For example. Myers and Sperry (1985) found that the ability to name letters and digits presented to the left visual field was related to the number of alternatives in the stimulus set: performance improved as the number of alternatives was reduced. In a similar vein, Corballis (1994) has reviewed the ability of split-brain patients to compare numerical stimuli directed to each hemisphere. Corballis concluded that the ability of split-brain patients to perform such tasks might be explained in terms of sophisticated strategies, in which crude information about one of the items (e.g. the digit flashed to the LVF) is transferred either sub-cortically, or via cross-cueing (to the left hemisphere), and then combined with detailed information about the identity of the other digit (flashed to the RVF and encoded within the left hemisphere). Corballis showed that detailed information about one digit, combined with rudimentary information about the other (e.g. whether greater or less than 5), could give rise to the high levels of accuracy which some commissurotomy patients have attained on tasks requiring cross comparison of digits flashed to opposite hemispheres.

An important difference between the current task, and those discussed by Myers and Sperry (1985) and by Corballis (1994) is that transfer of information in this task is *implicit* in the sense that task instructions make no reference to the LVF digit, save for the request to ignore it as irrelevant. In the tasks described by Myers and Sperry and Corballis subjects were explicitly instructed to make use of information from the LVF stimulus in arriving at a decision.

Conclusions

The two experiments reported in this paper show that even in the absence of cerebral commissures there are rich interactions between information processing in the left and right cerebral hemispheres. These inter-hemispheric interactions involve both facilitatory and inhibitory influences, most probably mediated via mid-brain pathways which remain undivided by the operation. Experiment 1 showed that such interactions can involve a complex cognitive attribute, such as the semantic category of a word. Experiment 2 showed that while these influences appear to operate with respect to categorical attributes of objects, they probably do not involve sub-cortical transfer of detailed information encoding object identity. Findings from this experiment, and from earlier studies (Lambert, 1991,1993) can be explained in terms of inter-hemispheric transfer of a simple binary code, representing the category (odd vs. even; living vs. non-living) of the unattended LVF stimulus.

Reference Note

Lambert,A.J. (1996). Facilitatory priming in a verbal negative priming paradigm. Unpublished experiment, University of Auckland.

References

Allport,A. 1989. Visual attention. In *Foundations of Cognitive Science,* M.Posner (Editor), pp.631-682. MIT Press, Cambridge, Mass.

Allport,A., Tipper,A. & Chmiel,N. 1985. Perceptual integration and post-categorical filtering. In *Attention and Performance XI,* M.Posner & O.Marin (Editors), pp.107-132. Lawrence Erlbaum, Hillsdale, N.J.

Bogen,J.E., Schultz,D.H. & Vogel,P.J. 1988. Completeness of callosotomy in the long term shown by magnetic resonance imaging. *Archives of Neurology, 45,* 1203-1205.

Bogen,J.E. and Vogel,P.J. 1975. Neurologic status in the long term following complete commissurotomy. In *Les Syndromes de Disconnexion Calleuse chez lHomme,* pp.227-251. F.Michel & B.Schott (Editors), Hopital Neurologique, Lyon.

Corballis,M.C. 1994. Split decisions: problems in the interpretation of results from commissurotomized subjects. *Behavioral Brain Research, 64,* 1994 163-172.

David,A.S. 1992. Stroop effects within and between the cerebral hemispheres: studies in normals and acallosals. *Neuropsychologia, 30,* 161-175.

Kinchla,R.A. 1992. Attention. *Annual Review of Psychology, 43,* 711-742.

Lambert,A.J. 1991. Interhemispheric interaction in the split-brain. *Neuropsychologia, 29,* 941-948.

Lambert,A.J. 1993. Attentional interaction in the split-brain: evidence from negative priming. *Neuropsychologia, 31,* 313-324.

Lambert,A.J., Beard,C.T. & Thompson,R. 1988. Selective attention, visual laterality, awareness and perceiving the meaning of parafoveally presented words. *Quarterly Journal of Experimental Psychology, 40A,* 615-652.

Myers,J.J. & Sperry,R.W. 1985. Inter-hemispheric communication after section of the forebrain commissures. *Cortex, 21,* 249-260.

Sperry,R.W. 1985. Consciousness, personal identity and the divided brain. In *The Dual Brain: Hemispheric Specialisation in Humans, D.F. Benson & E. Zaidel (Editors).* Guilford, New York.

Sperry,R.W., Zaidel,E. & Zaidel,D. 1977. Self recognition and social awareness in the deconnected minor hemisphere. *Neuropsychologia, 17,* 153-166.

Tipper,S.P. 1991. Less attentional selectivity as a result of declining inhibition in older adults. *Bulletin of the Psychonomic Society, 29,* 45-47.

Tipper,S.P. & Baylis,G. 1987. Individual differences in selective Attention: The relation of priming and interference to cognitive failure. *Personality and Individual Differences, 8,* 667-675.

Tipper,S.P. & Cranston,M. 1985. Selective attention and priming: inhibitory 2and facilitatory effects of ignored primes. *Quarterly Journal of Experimental Psychology, 37A,* 591-611.

Trevarthen,C. 1990. *Brain Circuits and Functions of the Mind: Essays in Honour of Roger W. Sperry.* Cambridge University Press, Cambridge.

Trevarthen,C. & Sperry,R.W. 1973. Perceptual unity of the ambient visual field in commissurotomy patients. *Brain, 96,* 547-570.

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