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DIFFERENTIAL PROCESSING OF TOPOGRAPHIC AND SYNTACTIC FUNCTIONS OF SPACE

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American Sign Language (ASL) uses space for several different functions. We will contrast the use of space to represent *syntactic* relations and to represent *spatial* relations. These two functions of space are not mutually exclusive and can co-occur. When the space within which signs are articulated is used to describe the layout of objects or people in space, the spatial relations among signs correspond in a topographic manner to actual relations among objects described. The linguistic conventions used in spatial mapping specify the position of objects in a highly geometric and nonarbitrary fashion by situating certain sign forms (e.g., classifiers) in space such that they maintain the topographic relations of the 'world-space' being described. We hypothesize that the topographic use of space is functionally distinct from the use of space to convey syntactic distinctions. During the comprehension of signed sentences, we hypothesize that two types of internal representations may be constructed. In processing ASL grammar, a syntactic representation must be extracted from spatially encoded syntactic relations; however, when space is used to map a real world scene or to describe a spatial array, a (possibly nonlinguistic) spatial representation may be extracted along with the syntactic representation of the sentence. We are investigating the nature of these representations, their interaction, their separability, and the time course of their construction during processing.

We will present three different studies which investigate 1) the neural underpinnings of topographic and syntactic spatial functions, 2) on-line processing of these different uses of space, and 3) their memory encoding. The results of each study argues for a functional distinction between the use of signing space to represent spatial relations topographically and the use of space to encode syntactic distinctions and relations.

Differential Impairment of Topographic and Syntactic Uses of Space

Some of the strongest evidence for a functional distinction between topographic and syntactic uses of space comes from adult deaf signers who have suffered brain injury to either the left or right cerebral hemisphere. Right hemisphere damage can impair a signer's ability to use space topographically (as when describing the layout of a room), but the use of space to convey pronominal distinctions and verb agreement is left intact (Poizner, Klima, and Bellugi, 1987). For example, one right hemisphere damaged patient (BI) produced a quite distorted spatial description of a room, piling all of the furniture onto the right half of space. However, when space was used for coreference and verb agreement, all of the signing space was utilized (including the left half of space). In contrast, a left hemisphere damaged aphasic signer (PD) produced correct (although simplified) spatial descriptions, but he often failed to use space correctly for pronominal reference or for verb agreement. Another left hemisphere damaged signer (KL) correctly indicated the spatial location and orientation of objects, but she failed to specify the referents of the classifiers that were used in her descriptions. Below we present results from another patient who suffered right hemisphere damage and who shows a clear dissociation between the use of signing space as a syntactic device marking grammatical relations and the use of signing space as a topographic mapping device.

Dissociation of syntactic and topographic functions following right hemisphere damage. Patient DN is a young hearing signer (age 37) who was exposed to ASL early in life. She is a certified interpreter for the deaf and is bilingual for English and ASL. Her father was a native signer, and DN grew up with her deaf grandmother. DN underwent surgical evacuation of a right parietal-occipital hematoma and an arteriovenous malformation and was tested approximately five months post operatively. Examination of an MRI scan done six months after the surgery revealed a predominantly mesial superior occipital-parietal lesion. The superior parietal lobule was involved while the inferior parietal lobule was spared, although some of the deep white matter coming from this structure may also be involved. We will focus on DN's linguistic abilities in ASL and her nonlinguistic spatial cognitive functions (see Corina, Bellugi, Kritchevsky, O'Grady-Batch, & Norman (1990) for a comparison of her English and ASL).[1]

Nonlanguage Visual-Spatial Skills*:* Like other signing patients who have right hemisphere damage, DN exhibits some disruption of nonlanguage spatial cognitive abilities. DN shows some impairment in her copying of the Rey Osterreith figure, and she shows substantial impairment in her ability to draw this complex figure from memory. DN also exhibits impairment on the WAIS block design task in which the subject must construct a specified pattern from a set of colored cubes. DN's errors are typical of right hemisphere damaged subjects in that she breaks the overall configuration of the pattern but preserves the local internal organization. DN appears to have particular problems with visuo-constructive tasks and with spatial memory.

Linguistic analysis: Spared use of spatial syntax. Despite the fact that DN has visuo-spatial impairments, she shows no linguistic deficits in ASL (she is also not

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[1] Poizner and Kegl (1992) also discuss this patient but use the pseudonym initials AS.

aphasic for English, see Corina et al., 1990). She exhibits excellent performance on the Sign Diagnostic Aphasia Exam. This exam includes tests for picture and confrontation naming, sign and finger-spelling discrimination, sign and phrase repetition, and comprehension of multipart ASL commands. DN's linguistic performance was excellent on all tests. Furthermore, we administered additional tests that specifically examined her use of space as a syntactic marker, and we analyzed her spontaneous and elicited signing for errors in the syntactic use of space (see below).

It is well known that noun phrase referents in ASL can be assigned arbitrary loci in space, and agreeing verbs mark grammatical subject and object by moving between these spatial loci (or changing orientation with respect to these loci). We gave DN a picture matching task in which she was presented with sentences such as: DOG INDEX$_a$ CAT INDEX$_b$ $_a$BITE$_b$ ("The dog bites the cat").[2] In this test, subjects are presented with two pictures, and asked to pick which one corresponds to the examiner's sentence. The pictures show either the correct grammatical assignment of subject and object (a dog biting a cat) or the reverse (a cat biting a dog). The spatial arrangement of the pictures do not necessarily match the spatial arrangement set up by the examiner. DN missed only two items on this test, scoring 86% correct (significantly better than chance, $p < .05$). In order to perform well on this test, DN had to remember the association of the nominals with arbitrary spatial loci and had to interpret the spatial verb morphology as marking subject and object.

An analysis of several samples of DN's signing revealed no deficits in the use of space to grammatically mark subject and object or sentence level pronominal reference. Below are some examples from DN's free conversation that illustrate her correct use of space to mark reference and grammatical agreement.

<u>Examples of correct use of verb agreement</u>

1) [my aunt] CALL$_b$ FRIEND SELF$_b$ NURSE ASK$_b$ RS$_{aunt}$<WHAT GOOD HOSPITAL FOR BRAIN PROBLEM> PRON$_b$ RECOMMEND PSYCHIATRIC HOSPITAL.
"My aunt called a friend who was a nurse and asked "What's a good hospital for neurological problems?" She (the nurse) recommended a psychiatric hospital."

2) ONE$_a$ FRIEND$_a$ HEARING $_a$BRING$_{1st}$ HER$_a$ T-T-Y. I $_{1st}$CALL$_b$ MY DEAF FRIEND.

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[2] Transcription information is given in Appendix B.

"One hearing friend brought me her T-T-Y. I called my deaf friend."

3) I $_{1st}$CALL$_{a}$ AUNT. $_{1st}$ASK$_{a}$ AUNT PLEASE $_{a}$COME $_{a}$PICK$_{1st}$ U-P DRIVE$_{b}$ HOSPITAL.
"I called my aunt. I asked my aunt to please come here and pick me up and drive me to the hospital."

Notice that DN establishes distinct loci for different referents and that she correctly articulates the agreeing verbs with respect to these loci. Notice also that she has command over certain types of spatial verbs such as COME and DRIVE. She correctly uses space to show change in location for these verbs. However, when we investigated her signing in more detail and under more demanding circumstances, we found that DN shows a marked impairment in the use of space to mark spatial locations and relations.

Analysis of topographic functions of space: Impaired spatial mapping. In this study, DN was asked to watch several signed stories that either involved spatial descriptions or did not manipulate space during the discourse. After viewing each 30 second story, DN had to immediately re-tell the story. A "mapping" story might be a description of a dentist's office or the layout of a parking lot in which objects are described topographically. The second type of story did not manipulate space extensively but relied on cues from word order, lexical identification, and nonmanual marking; example story topics included "Christmas Shopping" or "My Favorite Foods". The ten stories are listed in Appendix A and were also presented to native and non-native deaf signers for a separate study. Five non-native signers served as control subjects for DN since she was not exposed to ASL from birth. For the normal control signers, the story re-telling was slightly more demanding because while the subjects were watching the stories, they were required to `tap' with a telegraph key as quickly as possible (this manipulation was part of another experiment).

Our results were striking and definitive. DN was severely impaired in her ability to re-tell descriptions that relied on the topographic functions of space, and her errors were qualitatively different from errors made by control signers. Table 1a presents a summary of the accuracy of DN and the control subjects in remembering specific items and their spatial locations. DN does quite well in remembering the actual items within a description (unlike some of our normal controls), but she completely fails in her ability to place these objects in their correct spatial configurations. Control subjects correctly locate 90% of the items that they remember from the story; whereas, DN correctly locates only 36% of the items she remembers.

Table 1. Mean percentages of items/participants, locations, and events/descriptions remembered from target stories by control subjects (N=5) and patient DN.

A. Topographic Stories

	Percent of Items Remembered		Percent Correct Placement of Items Remembered	
	Controls	DN	Controls	DN
Story 2	72	75	95	46
Story 4	82	80	88	25
Story 5	68	60	72	33
Story 7	84	67	97	56
Story 10	86	83	97	20
Mean	78	73	90	36

B. Stories Told Without Using Space

	Percent of Items/Participants Remembered		Percent of Events/Descriptions Remembered	
	Controls	DN	Controls	DN
Story 1	84	100	65	93
Story 3	90	100	47	60
Story 6	---	---	75	71
Story 8	80	75	63	71
Story 9	100	100	82	89
Mean	89	94	66	75

Figure 1 illustrates her description of a dentist's office (story 4) in comparison to the correct description. DN's description shows a marked spatial disorganization of elements within the room; she incorrectly specified the orientation and locations of items of furniture. She tended to 'lump' all of the furniture within the center of the room; in addition, she also made errors in the use of classifiers. As Figure 1 shows, she erroneously uses a 'bucket' type classifier in her description of a magazine rack. These kinds of errors were never made by our normal controls. Typical errors for the controls involved forgetting certain items or slight shifts in the orientation of objects. The pattern of positioning all of the items in the center of signing space was typical for DN's spatial descriptions and never occurred in the control subjects' descriptions which were generally quite accurate.

Insert Figure 1 about here

Importantly, DN did not show this same disruption for remembering events or descriptions from the stories that did not make use of space. Moreover, despite the fact that the narrator of these stories did not use space for reference, DN (along with the control subjects) nonetheless used space to mark syntactic relations when retelling the stories. For example, in the story in which a boy is kidnapped (story 1), the narrator used word order rather than space to mark the grammatical relations subject and object, and agreeing verbs were produced as citation forms without reference to spatial loci. Referents were not associated with spatial loci. In contrast, when DN retold this story, she correctly established syntactic relations using spatial loci, and she correctly produced verb agreement morphology which incorporated these loci. Below is a transcription of DN's story:

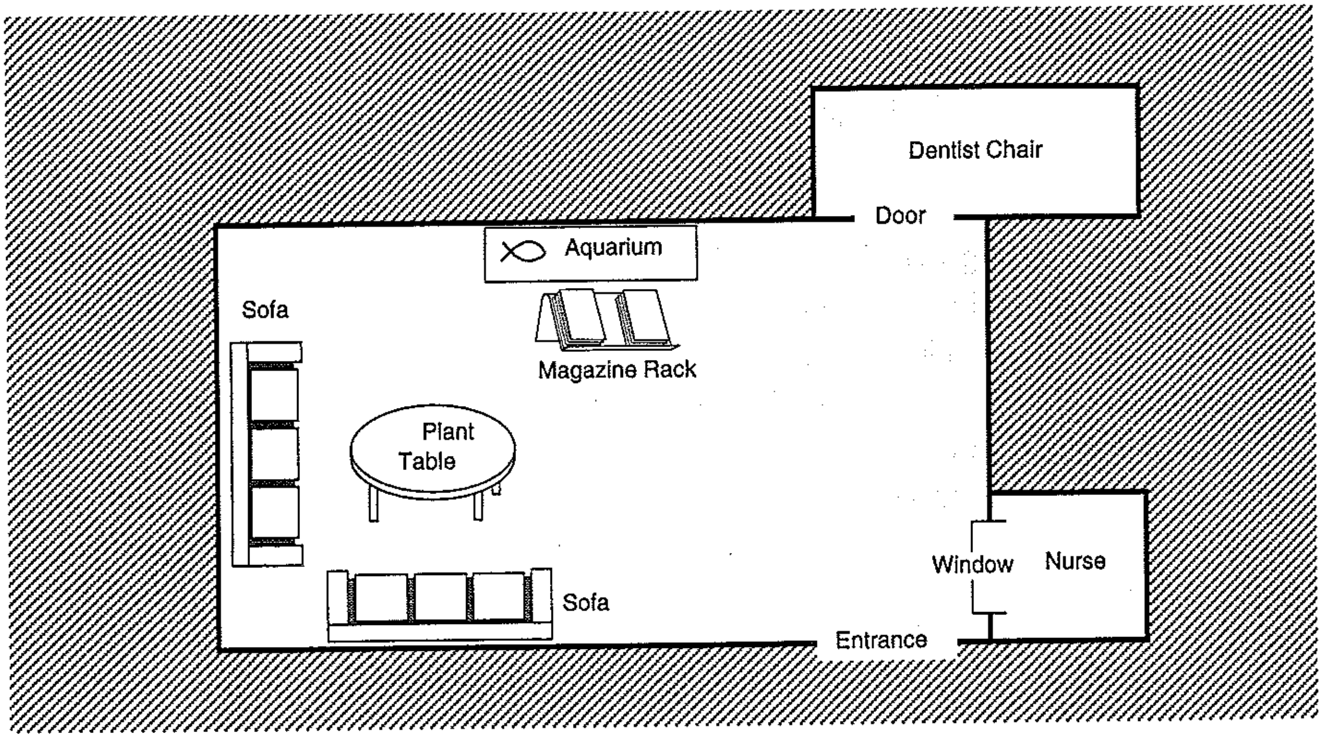
> BOY **SELF**$_a$ REALLY TROUBLE[continual] HARD CONTROL. ONE-DAY MAN NEED MONEY **GRAB**$_a$ K-I-D-N-A-P. **TOOK**$_a$ BOY **TOOK**$_a$. WRITE LETTER **SEND**$_b$ **HIS**$_a$ PARENTS. REQUEST FOR MONEY. FATHER READ LETTER. RS$_{father}$ < "WELL" DON'T CARE WHY$^{rh\text{-}q}$ **PRON**$_a$ BOY HARD CONTROL, TROUBLE **PRON**$_a$. "SHRUG" LET **PRON**$_c$ MAN TAKE-CARE-OF BOY>. **PRON**$_c$ MAN BECOME FED-U-P. WRITE LETTER **SEND**$_b$ FATHER. SAY RS$_{man}$<PLEASE TAKE **YOUR**$_b$ BOY. I PAY MONEY WILL I>.

> "There was a boy who was alot of trouble and hard to control. One day, a man needed money and kidnapped him. The man wrote a letter and sent it to his parents, asking for money. The father read the letter but he said "I don't care. Why? Because the boy is hard to control and trouble. Let the man take care of the boy." The man became fed-up. He wrote a letter and sent it to the father saying 'Please take your boy, I'll pay money!' ".

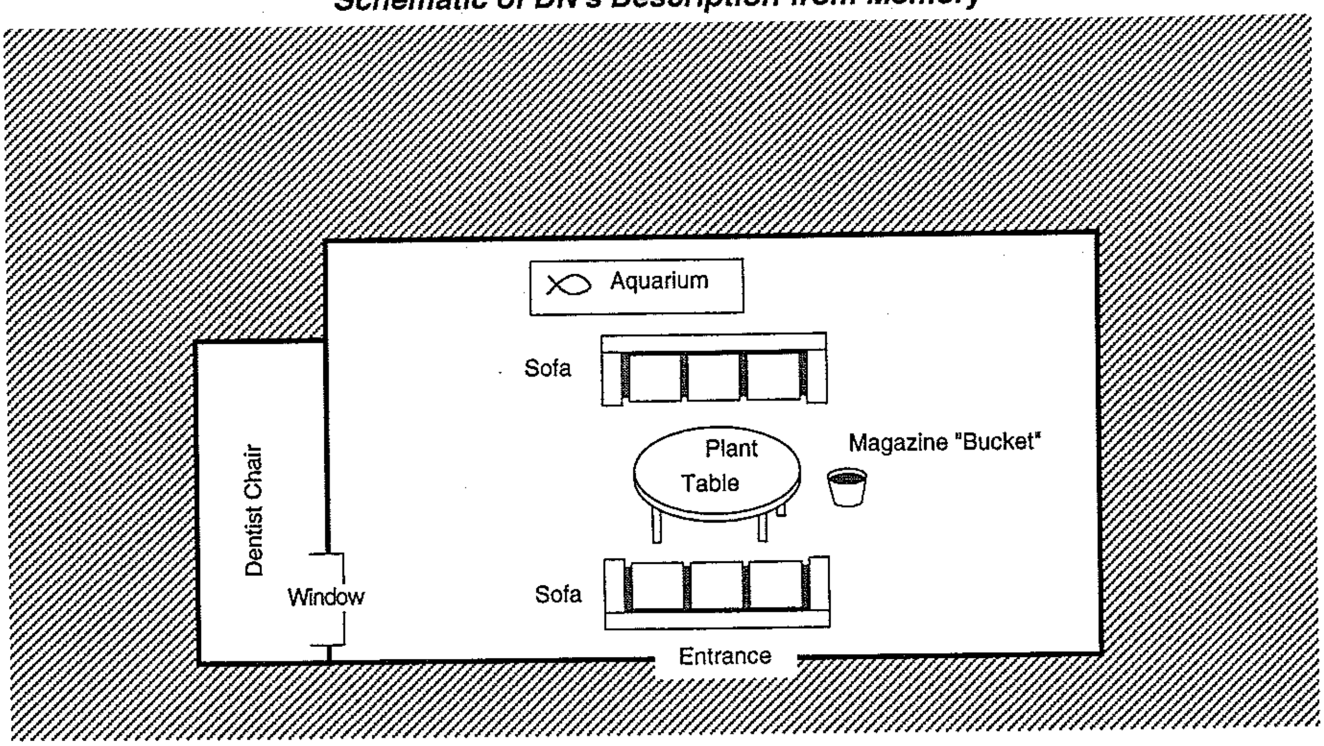
Table 1b shows that she was quite accurate in her memory for the participants and events of this story. Her retelling is almost verbatim -- **except** she uses space to establish syntactic relations rather than word order as was done in the original story (for

Figure 1. Breakdown of the Use of Topological Space Following Right Hemisphere Damage.

Schematic of the Target Room Described in the Narrator's Story



Schematic of DN's Description from Memory



experimental purposes). DN and the control subjects use the most natural device in ASL for marking grammatical relations and reference in ASL, i.e. space. Thus, even when DN has been encouraged to avoid the use of space as a syntactic device, she nonetheless prefers and uses spatial grammatical marking.

DN is one of several right hemisphere damaged patients that we have studied who show a dissociation between the use of space to specify grammatical relations and the use of space to indicate spatial relations. DN's impairment in the use of topographic space provides strong evidence that the right hemisphere is involved in processing topographic information. Given DN's impairment on nonlinguistic spatial tasks which required her to place objects in specific spatial relations to each other (e.g. in drawing and block design tasks), we hypothesize that DN's breakdown occurs at the level of conceptualization; and we observe this conceptual breakdown in her signing. Her breakdown in using topographic space is not a linguistic deficit per se -- rather, her spatial cognitive deficit becomes apparent in her signing because ASL grammar requires explicit coding of spatial relations for descriptions of objects in the world, and these relations must be encoded using space itself. Therefore, her conceptual deficit in perceiving real world spatial relations is reflected in her linguistic expression of these spatial relations and in her inability to understand such linguistic descriptions.

Since the use of space to convey syntactic relations and the use of space to convey topographic relations can be differentially affected by brain damage, we hypothesize that topographic and syntactic uses of space may have different mental representations and processing demands. We investigate this hypothesis in the following two studies.

Processing Topographic and Syntactic Uses of Space

As we have noted, when space functions topographically within a linguistic description, geometric information is represented in an analog fashion; spatial loci function not only as linguistic points, but as counterparts to physical locations in the world (or in an imagined world). This is in marked contrast to the situation in spoken languages, in which the topographic information must be recovered from a linguistic signal which does not map onto the information content in a one-to-one correspondence. This system is of particular interest for processing in that the two different types of information -- linguistic and topographic -- are directly represented in the linguistic structure and may necessitate a dual representation.

To investigate how subjects interpret space that functions syntactically versus topographically, we used a probe recognition technique. In this task, subjects viewed signed sentences and then decided as quickly as possible whether a "probe" sign had appeared in the sentence. Probe signs were articulated either at a locus that was congruent with the noun phrase in the test sentence or at an incongruent locus. We predicted that if the probe sign was articulated with the incorrect indexation, subjects should be slower to recognize that the probe occurred in the sentence. Furthermore, we predicted that this interference would be most severe for sentences in which the spatial loci functioned topographically compared to syntactically. Reaction times should be slower for "topographic" sentences because a locus actually **represents** a spatial location and performs a semantic function. In the "syntactic" sentences, the locus is arbitrary and does not play the same kind of semantic role; the locus merely serves the syntactic function of establishing a spatial index for reference. Because of the semantic role played by loci in the topographic sentences, we should observe much slower response times to probes which are incongruent with the loci in the test sentence.

Method

Subjects

Twenty-four deaf subjects participated in the experiment. Twelve subjects were native signers with deaf parents (mean age = 23 years; SD = 3 years). Twelve subjects had hearing parents and were non-native signers (mean age = 30 years; SD = 12 years). The mean age at which non-native signers began to learn ASL was 9 years (SD = 5 years). All subjects had been signing for at least 5 years, and the mean number of years of signing experience was 20 years (SD = 13.6 years). Native and non-native signers did not differ significantly in the number of years of signing experience. Twenty-one subjects were born deaf, and three became deaf before age two. Subjects were tested either at Gallaudet University or at the Salk Institute and were paid for their participation.

Design and Materials

Figures 2a and 2b provide illustrations of test stimuli. In example sentence 2(a), the spatial loci represent a topographic mapping of a scene in which the spatial loci stand in specific relationships to each other, and these relationships are non-arbitrary. Example 2(b) illustrates a "syntactic" sentence in which the loci are arbitrary and bear no inherent relation to each other. Great care was taken to ensure that these sentences could not be construed as having any kind of real world spatial representation. There were 48 test sentences (24 topographic and 24 syntactic) and 52 filler sentences. The probe was articulated simultaneously with an index that was directed toward the correct or incorrect locus. Subjects were told to decide whether the probe word itself was used in the sentence regardless of indexation. Filler probes ("no" responses) were either phonologically or semantically related to a word in the test sentence and were produced with indexation as were the test probes (always a "yes" response, see Figure 2). Two videotapes were constructed which counterbalanced probe congruency of the test items. The filler sentences were the same for both videotapes, and subjects saw only one videotape.

Insert Figure 2a and 2b about here

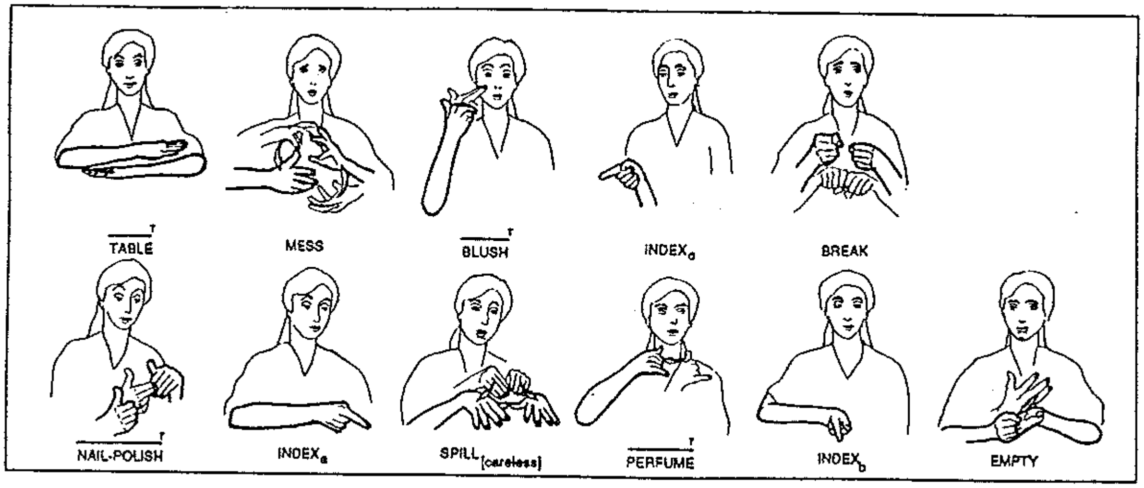
Results and Discussion

Our predictions were confirmed (see Figure 3). Incongruent probe loci produced much greater interference when the space functioned topographically compared to when space functioned syntactically. Reaction times were not significantly longer for incongruent probes in the syntactic condition ($F < 1$), but the difference between the congruent and incongruent probes for the topographic condition was highly significant ($F(1,22) = 10.55$, $p < .01$). The amount of interference caused by a spatially incongruent probe was three times as great in the topographic condition ($\bar{x} = 63$ msec) compared to the syntactic condition ($\bar{x} = 20$ msec).

In addition, subjects made more errors on sentences in which the loci functioned topographically compared to syntactically ($F(1,22) = 7.83$, $p < .05$), but sentence type did not interact with probe type (congruent or incongruent) in the error rate analysis. Subjects were generally quite accurate on this task ($\bar{x} = 93\%$ correct), and there was no difference between native and non-native signers for either accuracy ($F < 1$) or reaction time ($F < 1$). However, there was a difference between native and non-native signers in their response to filler items (the "no" responses). Both groups had slower rejection times for probes that were semantically related to a sign in the test sentence (e.g. PARENTS/FAMILY) compared to when the probe and sign were phonologically related (e.g., ONION/KEY). However, the non-native signers had much longer rejection times for probes that were phonologically related compared to native signers (see Figure 4). This finding is consistent with those of Rachel Mayberry and colleagues who have found that non-native signers allocate more attention and effort in decoding ASL phonology (Mayberry and Eichen, 1991; Mayberry and Fisher, 1989). If non-native signers retain more of the phonological representation of a sentence in working memory (see Mayberry, this volume), then they would be slower to reject a phonologically related probe sign compared to native signers who have quickly processed (and possibly discarded) the phonological form of the sentence.

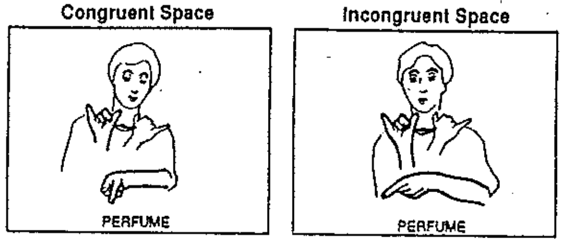
Insert Figures 3 and 4 about here

Figure 2a. Example of Topographic Use of Space



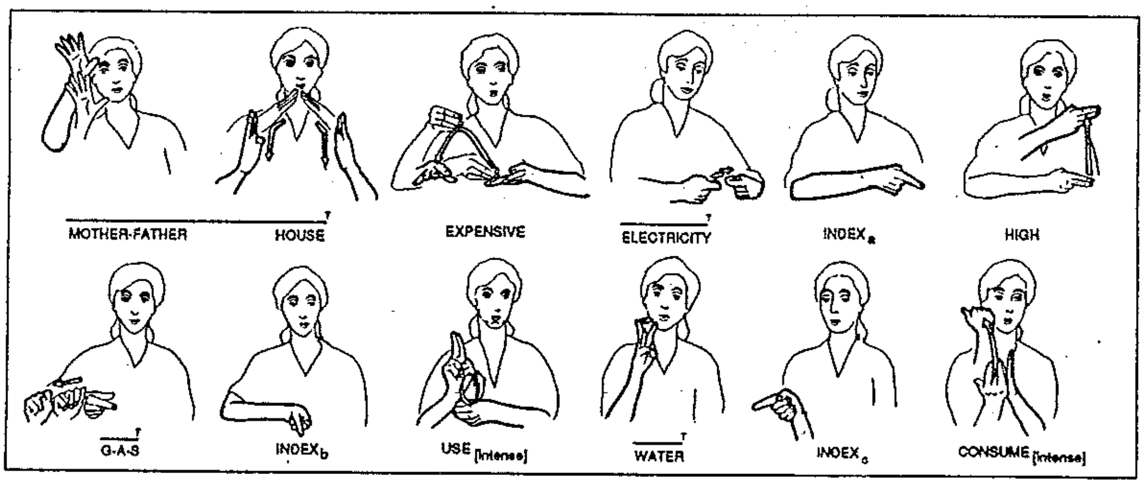
Probes:

Congruent Space | Incongruent Space



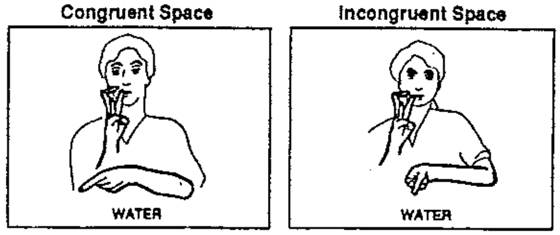
English Translation:
"My (vanity) table is a mess. The case for my blush which is on the right is broken. My nail polish on the left has spilled, and my perfume bottle in the center is empty."

Figure 2b. Example of Syntactic (Arbitrary) Use of Space



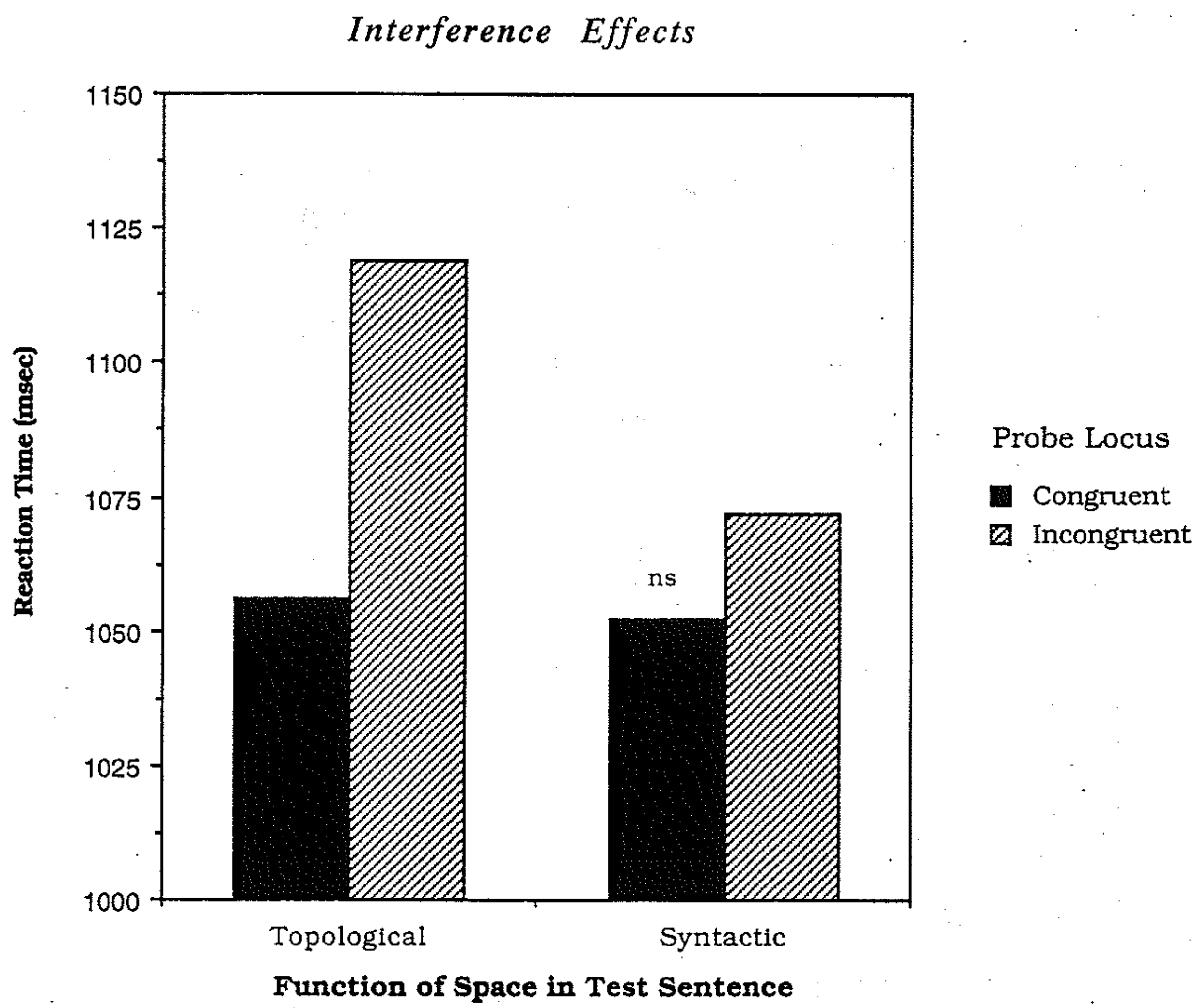
Probes:

Congruent Space | Incongruent Space



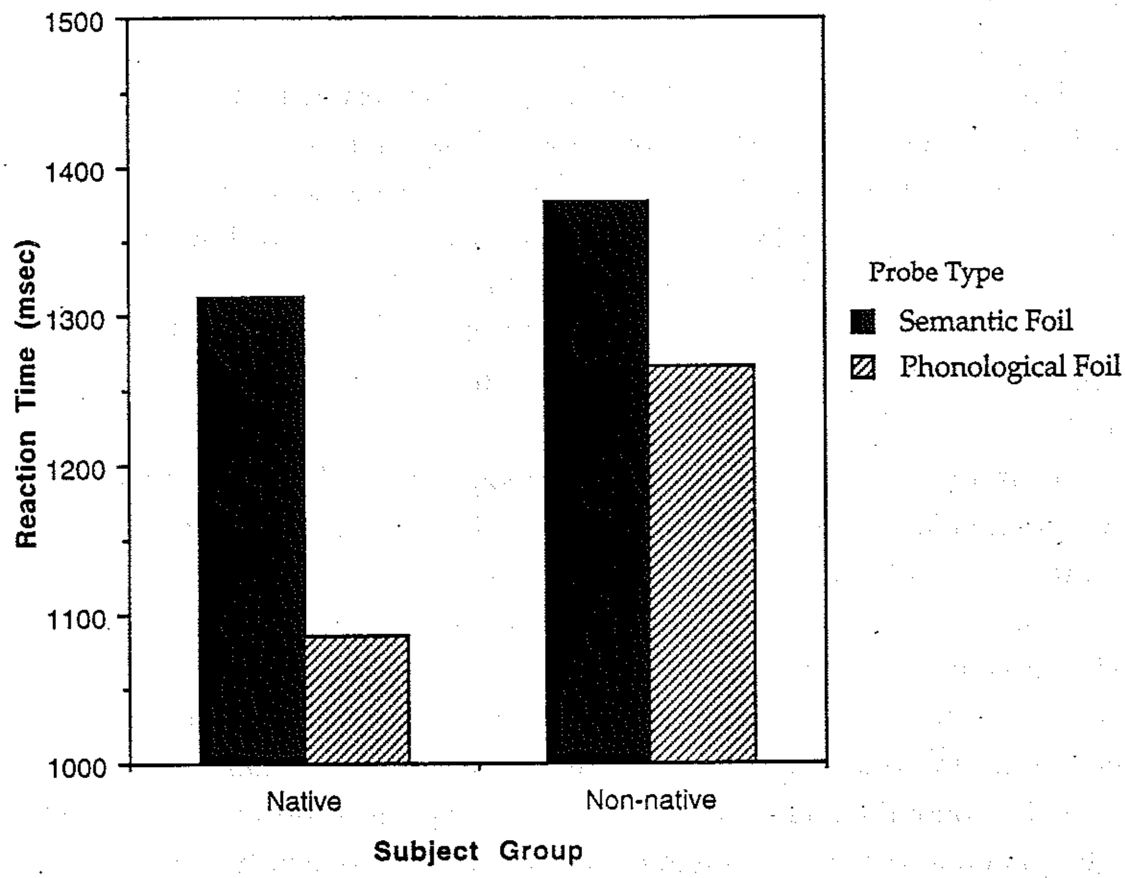
English Translation:
"My parents' house is very expensive - their electric bills are high, they use a lot of gas and go through a lot of water."

Figure 2. On-Line Construction of Spatial Representations: Examples of Aribitrary and Topographic Space



Interference Effects
1150
1125
1100
1075
1050
1025
1000
Reaction Time (msec)
ns
Topological
Syntactic
Function of Space in Test Sentence
Probe Locus
Congruent
Incongruent

Probe Rejection



Overall, these results suggest that the mental representations for topographic and syntactic spatial functions differ in a non-trivial way. There appears to be a much stronger relationship between a spatial locus and its associated nominal when that locus represents a possible real world spatial layout. Subjects were unable to suppress their recognition of a spatially incongruent probe in the topographic condition, but when sentences contained arbitrary spatial loci that played no particular semantic function, subjects were able to suppress recognition of an incongruent index and showed little interference effect.

DN was also presented with this task, and her results indicated that she was not sensitive to the topographic import of the spatial loci in the topographic condition. Like normal subjects, DN showed no interference for incongruent probes in the syntactic condition ($F(1,22) = 1.15$), but unlike normal subjects, DN also showed no interference for the incongruent probes in the topographic condition ($F < 1$).[3] In fact, for both conditions, incongruent probes actually had faster response times. DN's performance on this task is consistent with her inability to correctly use space for topographic descriptions.

Thus, the ability to utilize space for topographic and syntactic functions not only shows differential impairment following brain damage, but these functions of space are also processed differently by the normal intact brain. When subjects must interpret spatial loci as conveying topographic information, the mental representation of these loci in association with their referent nominals may be much more explicit, encoding the inter-relation between loci and objects, as well as other spatial features, such as orientation. In contrast, the mental representation of spatial loci whose primary function is pronominal reference need not be as explicit -- subjects must merely encode rough location in space as signifying a contrast between one or two referents. Such loci do not *necessarily* convey spatial information about their referents and can be completely arbitrary.

In the next study, we examine how these mental representations are maintained in memory for longer periods of time. The above experiment probed the immediate memory structure which may contain more of the surface syntactic representation of the sentence. In the following experiment, we investigate subjects' recognition memory for spatial loci and their associated referents for the same sentences used in the above study, but over longer time periods.

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[3] DN's reaction times for each item were entered into an ANOVA with sentence type and probe type as the independent variables.

Memory for Topographic and Syntactic Spatial Functions

Previous research has shown that what is remembered about a given English utterance is its meaning, and not all aspects of its literal form (e.g., Sachs, 1967). After a delay, some details of surface structure are lost. Hanson and Bellugi (1982) found that after a delay, signers did not recognize structural changes that created a paraphrase of the original ASL sentence (e.g. substituting SICK[habitual] for the phrase OFTEN SICK). These results suggest that signers and speakers retain the meaning of sentences better than they retain the exact linguistic structure that expresses this meaning. We hypothesized that when spatial loci function topographically they carry semantic import and may be stored as part of the semantic representation of the sentence. When loci function syntactically, these specific loci may not be retained in memory because they serve as referential indices only. Of course, referential loci must be retained within a specific discourse, but once this discourse is over, then the addressee (and signer) need not remember the association between a referent and a particular spatial locus. However, when these loci function topographically, the particular spatial relation between one referent and another (as encoded by their associated loci) should be remembered as significant -- that is, these loci are not arbitrary, but form part of an explicit spatial description.

To investigate this hypothesis, we used a continuous recognition memory task in which subjects are presented with blocks of sentences and must decide for each sentence whether it has been previously seen. Target sentences contained either a lexical change (substitution of one sign for another) or a spatial change (reversing the spatial loci associated with two referents). We predicted that lexical changes would be noticed more than spatial changes because lexical changes create a greater difference in meaning. Moreover, we predicted that for sentences in which the loci functioned topographically, subjects would notice the spatial changes much more frequently than for sentences in which the loci functioned syntactically. No difference between sentence types was predicted when the changes were lexical rather than spatial.

Method

Subjects

Thirteen native deaf signers participated in the experiment (mean age = 26 years; SD = 7.5 years). All subjects were tested at Gallaudet University and were paid for their participation.

Materials and Design

The sentences in this experiment were a subset of those used in the previous experiment (see Figures 2a and 2b). However, these sentences (along with selected filler sentences) were refilmed with a different native signer. The experimental design was 2 (sentence type: topographic/syntactic) X 2 (type of alteration: lexical/spatial) X 3 (delay: early, medium, late). For the early delay, 2 sentences intervened between the first and second occurrences of the target sentence; for the middle delay, 5 sentences intervened, and for the late delay, 9 sentences intervened. Four target sentences occurred in each condition, creating a total of 48 test sentences. To create the correct delays, these sentences were interspersed with filler sentences with similar lengths and structures. The following are examples of test stimuli with lexical and spatial changes:

Topographic Sentences

Original:
MY NEW HOUSE HAVE HALLWAY[center] BIG, BATHROOM INDEX[right] FRENCH, BEDROOM INDEX[center] ITALIAN, LIBRARY INDEX[left] BRITISH.

Change in Spatial Loci:
MY NEW HOUSE HAVE HALLWAY[center] BIG, BATHROOM INDEX[right] FRENCH, BEDROOM **INDEX[left]** ITALIAN, LIBRARY **INDEX[center]** BRITISH.

Change in Lexical Items:
MY NEW HOUSE HAVE HALLWAY[center] BIG, BATHROOM INDEX[right] FRENCH, **KITCHEN** INDEX[center] ITALIAN, **DINING-ROOM** INDEX[left] BRITISH.

Syntactic Sentences

Original:
MY FAMILY REAL SMALL HAVE ONE UNCLE INDEX[left] SWEET, AUNT INDEX[center] STRICT, COUSIN INDEX[right] FRIENDLY.

Change in Spatial Loci:
MY FAMILY REAL SMALL HAVE ONE UNCLE **INDEX[center]** SWEET, AUNT **INDEX[left]** STRICT, COUSIN INDEX[right] FRIENDLY.

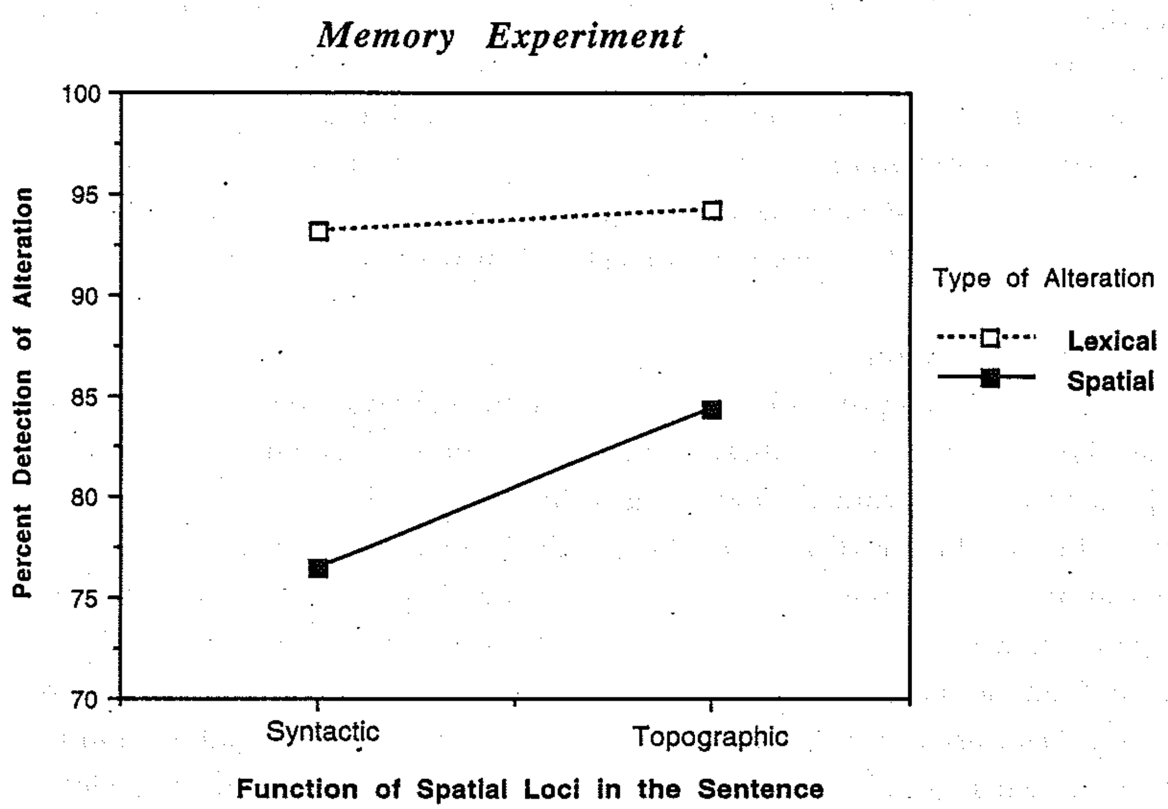
Change in Lexical Items:

MY FAMILY REAL SMALL HAVE ONE **SISTER** INDEX[left] SWEET, **GRANDFATHER** INDEX[center] STRICT, COUSIN INDEX[right] FRIENDLY.

Sentences were grouped into 12 trials varying in length from 10 to 15 sentences. Sentences from preceding trials often appeared in later trials, but subjects were told that each trial was independent. Thus, if a sentence had appeared in Trial 8, but was the first sentence in Trial 10, it would be considered a "new" sentence. This repetition was designed to make the task more difficult and to provide the opportunity for more errors. There were two practice trials in which subjects were given feedback. Subjects indicated on an answer sheet whether a given sentence was new or old and provided a confidence rating for their decision. All instructions were given in ASL.

Results and Discussion

The results support our hypothesis. Figure 4 shows the percent of spatial and lexical alterations that were noticed by subjects for topographic and syntactic sentences. Subjects were significantly worse at noticing changes in spatial loci compared to changes in lexical items ($F(1,12) = 29.46$, $p < .001$). In addition, when space functioned topographically, subjects were significantly more likely to notice a spatial change compared to when space only functioned syntactically ($F(1,12) = 4.82$, $p < .05$). There was no difference between sentence types for detecting lexical changes, suggesting that the sentences were well-matched (that is, syntactic sentences were not inherently more difficult to remember). Finally, there was no overall effect of delay, but delay interacted with sentence type and type of alteration ($F(2,24) = 6.14$, $p < .007$). For lexical alternations, delay had little effect on detection rate for either type of sentence -- subjects were quite good at recognizing lexical changes, never scoring below 90% correct for either the topographic or the syntactic sentences. However, for changes in spatial loci, subjects performed particularly poorly at the middle delay (5 sentences intervening), but only for sentences in which these loci functioned syntactically (67% correct detection). In contrast, subjects detected 92% of changes in spatial location for the topographic sentences at the middle delay. This difference in detecting spatial alterations for topographic and syntactic sentences was not apparent at the early and late delays. It is unclear why this difference is so strong at the middle delay and does not continue at the later delay (in fact, performance for the syntactic sentences improves at the late delay). It is possible that the middle delay is tapping an intermediate stage of


Memory Experiment
Percent Detection of Alteration
100
95
90
85
80
75
70
Syntactic
Topographic
Function of Spatial Loci in the Sentence
Type of Alteration
Lexical
Spatial

memory decay in which spatial information carried by the surface form of ASL is differentially affected, depending upon its function.

In conclusion, our results indicate that memory for spatial information which simply distinguishes referents is easily lost whereas memory for spatial information that directly encodes spatial relations is more accurately maintained and less subject to disruption from intervening material. Spatial loci that convey information about the actual spatial location of its associated referent may be specifically encoded in memory, perhaps as part of a semantic representation; whereas spatial loci that are used to distinguish referents or convey grammatical relations may not be encoded in the same way and may be more likely to fade from memory once their syntactic function is no longer required by the discourse.

Summary

We have presented evidence from three different studies that support the distinction between topographic and syntactic functions of space in ASL. First, these two functions can be dissociated with brain injury. Second, during on-line processing subjects represent the association between referents and spatial loci differently, depending upon whether the space subserves topographic or purely syntactic functions. Third, we presented evidence for differential memory encoding for sentences in which space functions topographically vs. syntactically. The results from the first study suggest that the topographic use of space may be tightly linked to spatial cognitive abilities subserved by the right hemisphere. The second and third studies suggest that when space functions topographically, the association between a referent and its assigned spatial locus may be represented as part of the semantic representation of the sentence.

Although we have emphasized the separability and distinctness of these two spatial functions, it is important to note that they are not mutually exclusive. The same signing space can be used to convey syntactic and topographic relationships simultaneously. Furthermore, it is important to stress that we are discussing spatial *functions*, not *types* of space. That is, there is not a "topographic space" that is separate from and inconsistent with a "syntactic space." Rather, space in ASL is multifunctional, and these functions can be expressed simultaneously. If a particular use of space encodes or conveys syntactic information, we would consider this use a syntactic function of space. If a particular use of space encodes topographic information, then we would consider this a topographic function. The function of the spatial relation is determined by the type of information encoded in that relation.

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Appendix A

Topographic Stories

Story 2: Description of file drawers and contents

Story 4: Dentist office (see Figure 1)

Story 5: Thanksgiving table

Story 7: Description of strange woman

Story 10: Parking lot (search for a motorcycle)

Stories without Space

Story 1: Kidnap of a boy (see description in text)

Story 3: Christmas shopping

Story 6: Philosophy of life

Story 8: Favorite foods

Story 9: Activities on Thanksgiving day

Appendix B

ASL Transcription Notes

Words in capital letters represent English glosses for ASL signs. A bracketed word following a sign gloss indicates a change in meaning associated with grammatical morphology in ASL (e.g., $\text{SPILL}_{\text{[careless]}}$). Multiword glosses connected by hyphens are used when more than one English word is required to translate a single sign (e.g., NAIL-POLISH). Subscripts are used to indicate spatial loci; nouns, pronouns, and agreeing verbs are marked with a subscript to indicate the loci at which they are signed (e.g. INDEX_a, ${}_a\text{ASK}_b$). Subscripted numerals may also be used to indicate first, second, or third person (e.g. INDEX_{1st}, ${}_{1st}\text{ASK}_a$). Superscripts indicate the syntactic or discourse function of a particular word or clause (e.g., topic (t), rhetorical question (rh-q)), and the scope of the function is indicated by a raised line covering the word or phrase. RS stands for "referential shift" and the subscripted noun indicates the referent of the shift (e.g. $\text{RS}_{\text{father}}$ <text>). The scope of the role shift is indicated by brackets.