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COMPREHENSION OF SPATIAL AND CONTEXTUAL INFORMATION IN PICTURES--ETC(11)
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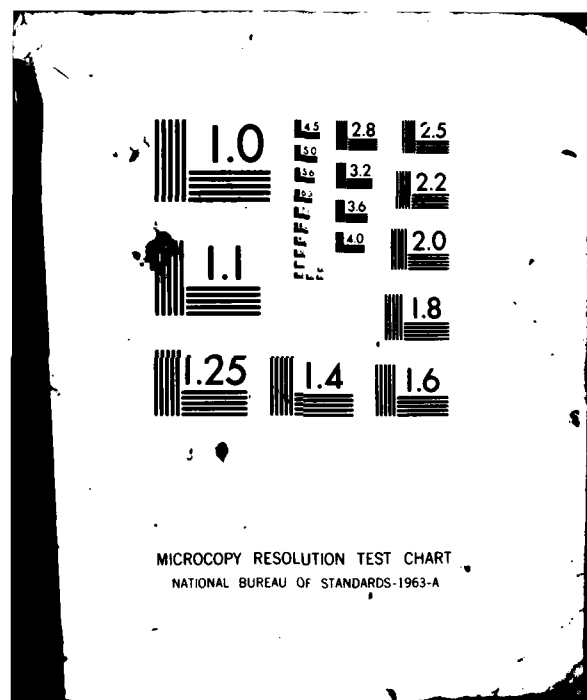
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Abstract

The information content of picture-text instructions for two assembly tasks was classified according to a taxonomy of information (Bieger, 1982). The location, in picture or text, of spatial, contextual, and operational information was then experimentally manipulated and the effect on comprehension was assessed by measuring the speed and accuracy of performance of 120 undergraduate students. It was found that textual presentation of spatial information produced fewer errors, while pictorial presentation of spatial information reduced performance times dramatically. It was further found that pictorial presentation of contextual information substantially reduced assembly times and slightly reduced the number of assembly errors. There were no differences between pictorial and textual depiction of operational information. Results are discussed in terms of implications for the design of instructional materials and the acquisition of information from picture-text materials.

COMPREHENSION OF SPATIAL AND CONTEXTUAL
INFORMATION IN PICTURES AND TEXTS

Very little research has been conducted to examine how different kinds of information are acquired differently depending on how they are presented. The research that has examined the use of pictures with texts has been plagued with a variety of theoretical and methodological problems, not the least of which included difficulties in describing the information content of texts and pictures in comparable terms. Some recent attempts to address that problem (Stone, 1980; Pine & Bieger, 1980) have used modifications of text analysis procedures to develop a list of propositions which can represent the semantic content of materials comprised of texts and pictures in a way that it is somewhat comparable. Most recently, a taxonomy of information categories, developed by Bieger (1982), has been used to describe the semantic content of pictures and texts in terms of functional categories of information. The categories of information in this taxonomy include Spatial, Operational, Descriptive, Inventory, Contextual, Covariant, Temporal, Qualifying, and Emphatic information. It was found that all of the information in several procedural assembly tasks could reliably be classified in one of these categories. It was further found that several of these categories of information, namely: Spatial, Operational, Inventory, and Contextual, were generally presented at every stage of the assembly, and that when materials were used in which one or more of these kinds of information were missing, both the speed and accuracy of performance deteriorated markedly. The purpose of the research reported here was to examine more closely the effect on performance of presenting some categories of information in text as opposed to picture.

Pictures can serve many functions when used as adjuncts to text. Several researchers (Vernon, 1953; Samuels, 1970; Gombrich, 1972; Kennedy, 1974) have

pointed out the usefulness of pictures in arousing the interest of readers and motivating them to read. The current research intended to focus on the more clearly cognitive aspects of pictures and texts as conveyors of information. Pictures, by their very nature, seem particularly well suited to the depiction of spatial information. It is often much easier to depict pictorially the spatial relationships among objects than to describe those relationships in text. However, the specific aspects of spatial relationships may be able to be described in better detail verbally. Therefore, it was hypothesized that pictorial depiction of spatial information would produce faster assemblies, but that textual depiction of that same spatial information would produce fewer errors.

Bransford and Johnson (1972) demonstrated that pictures can provide contextual information which renders otherwise meaningless text comprehensible. Since such content can be depicted with less ambiguity in pictures than in text, a second hypothesis was that pictorial depiction of contextual information would produce faster and more accurate assemblies than would textual depiction of context.

The last experimental hypothesis was related to the depiction of operational information. Since still pictures are inherently static, it is difficult to depict operations which are frequently dynamic. There are, of course, a variety of graphic conventions that can be used to depict motion in a static form. Since this research intended to examine the role of pictures versus texts, it was decided to study pictures without embellishment, that is, simple line drawings. Therefore, since the pictures lacked much of the specificity regarding operational information, it was expected that faster and more accurate performances would occur when operational information was depicted textually rather than pictorially.

Method

Subjects

One hundred and twenty undergraduate students, enrolled in various courses, volunteered to participate in this research and were randomly assigned to one of twelve experimental groups.

Materials

- a) Assembly parts for two tasks. One task was the assembly of a model hand truck using plastic block-like parts. The second task was the construction of a wall hanging using pre-cut pieces of felt.
- b) Digital stop clock to record assembly times
- c) Video-tape camera and recorder
- d) Instructions for the two tasks, prepared and analyzed according to the procedures described by Bieger (1982). Instructions were designed to convey various combinations of operational, spatial, and contextual information. The twelve different combinations are indicated in Figures 1 and 2. Each combination was used by ten subjects. For each instructional combination there was a complementary combination. For example, the instructional set comprised of a contextual text and operational picture [T (C) P (O)] had as its complement the combination comprised of the operational text and contextual picture [T (O) P (C)].

Procedures

After being briefed on the purposes of the research, subjects were introduced to the assembly parts for the first task. When subjects had mastered the part names, they were randomly assigned to one of twelve instructional conditions and were told to read and follow the instructions. Assemblies were

scored for time and accuracy and the assemblies were also video-taped in order to allow another scorer, independently, to rate the accuracy of each assembly. When subjects had finished with the first task, they were given the complementary set of instructions for the second task. The order of the two tasks was systematically counterbalanced--after completing the second task, subjects were debriefed and asked to complete a short form on which background information about subjects was recorded.

Results

Performance data (assembly times and number of errors) were recorded for both the model hand truck task and the felt wall hanging task and are shown in Figures 1 and 2 respectively. A comparison of these data revealed that performance in both tasks followed similar patterns in the various instructional conditions presented.

Insert Figures 1 and 2 about here

Each of these six pairs of instructional conditions was analyzed separately for any possible effects on speed or accuracy of performance, using a three factor ANOVA. The primary factor of interest was presentation mode (i.e., instructional set). Two complementary presentation modes were compared in each ANOVA. A second factor, called group, indicates whether for one group, the subjects assembled the hand truck following a given instructional set and the felt task following the complementary instructional set, or for the other group, whether the subjects assembled the felt task for the given instructional set and the hand truck for the complementary instructions. The third factor, subjects,

was nested within group. Subjects were crossed with presentation mode, thus adding precision to the test of the differences between presentation modes. Order effects were not analyzed in these analyses, but order was counter-balanced in the design.

The group factor is of little interest because subjects were randomly assigned to groups. The group by presentation mode interaction is of interest because its presence would indicate that differences between the presentation modes depend upon which task was done following which instructional set.

Differences in performance on the two assembly tasks were not compared since it is of little interest to know that one task is harder than another. Indeed, for the ANOVAs, errors and assembly times were each converted to z scores (i.e., mean = 0 and standard deviation = 1). This eliminated variation due to assembly task and made it sensible not only to compare presentation modes even though, within groups, they referred to different tasks, but also to use each subject as his/her own control in the repeated measures design.

Operational information alone [T (O) P (N) versus P (O) T (N)]. Figures 1 and 2 indicate that there was only a small difference in performance scores between picture and text presentation of operational information when it was the only category of information presented. These differences were found to be statistically insignificant.

Operational and spatial information [T (O + S) P (N) versus P (O + S) T (N)]. Figures 1 and 2 show that for both tasks, assemblies were performed considerably faster when the operational and spatial information were presented pictorially. This difference was found to be highly significant over both tasks [$F(1,18) = 100.130, p < .0001$]. Figures 1 and 2 also indicate a small difference in errors between these two conditions, with the text condition being slightly more accurate. This difference, however, was found not significant.

Operational and contextual information [T (O + C) P (N) versus P (O + C) T (N)]. Figures 1 and 2 show that performances on together in either pictures or text and operational and contextual information paired together in the opposite mode produced the same pattern of effects. That is, when the operational and spatial information were in the picture, subjects performed the assemblies in significantly less time [$F(1,18) = 19.510$, $p < .001$] but made significantly more errors [$F(1,18) = 7.250$, $p < .02$] than when operational and spatial information were in the text.

Additional comparisons between group means were done separately for each task and for each performance measure, between conditions T (C) P (O + S) and T (O + C) P (O + S), and conditions T (O + S) P (C) and T (O + S) P (O + C). These analyses examined the effect of redundant operational information being "added" to another condition. There were no differences, on either task, in number of errors and the differences in assembly time were small (see Figures 1 and 2) and was found statistically insignificant.

Similarly, comparison of conditions T (O + S) P (C) and T (O + S) P (O + C) revealed that the differences between these conditions, on both dependent measures and for both tasks, were small (see Figures 1 and 2) and were found statistically insignificant.

Finally, comparisons were done on all performance data between the various levels of the following factors: sex, age, class, major, and college of subjects; as well as experimenter and scorer. No significant differences due to any of these factors emerged from these analyses.

Discussion

The efficiency of the mode of presentation can be discussed in relation to

its effect on speed and accuracy of performance for each of the three categories of information.

Operational information. There was little or no effect, neither on speed of performance nor accuracy of performance, for different modes of presentation of operational information. The comparison of conditions T (N) P (O) and T (O) P (N), where operational information was presented alone either in text or in picture, indicated no discernible difference in either the assembly times or the number of errors. The differences between other conditions involving operational information may have been due, not to the mode of presentation of the operational information, but to the mode of presentation of the information with which the operational information was paired.

Comparison of conditions T (C) P (O + S) - T (O + C) P (O + S) and T (O + S) P (C) T (O + S) P (O + C) gives further insight into the importance, or apparent lack of importance, of redundant operational information in these tasks. The only difference between T (C) P (O + S) and T (O + C) P (O + S) is that operational information has been added to the textual portion of the instructions, and the only difference between T (O + S) P (C) and T (O + S) P (O + C) is that operational information has been added to the pictorial portion of the instructions. The fact that these additions make no noticeable difference in either assembly time or errors suggests that the addition of operational information has no effect on performance. This may be due, at least in part, to the fact that the kind of information characterized as operational was very general and perhaps of insufficient detail to be helpful in specific assembly procedures. Future investigations might examine this further by providing more specific operational information, such as using words like "slide," "insert," etc. instead of the more general terms, "connect," "attach," etc..

Contextual information. There were four combinations in which contextual information was presented in this study: (1) alone in picture or text and opposite operational information alone; (2) alone in picture or text and opposite operational and spatial information; (3) with operational information in picture or text and with nothing in the other mode; and (4) with operational information in picture or text and opposite operational and spatial information. In the combinations where there was no spatial information presented in either mode, there was a substantial reduction in assembly time, and a slight reduction in the number of errors, when the contextual information was presented in pictures rather than in text. The combinations in which spatial information was also presented presents a somewhat more complicated case which will be examined following the discussion of the effects of spatial information below.

It is important to remember that the level of contextual information that was present in these instructions was only the most general kind. There was no local contextual information whatsoever provided in any of the instructions used in these tasks. Therefore, any conclusions regarding the effects of mode of presentation of contextual information on performance must be tempered by the awareness that local context, and its mode of presentation, may affect performance differently.

Spatial information. There were three combinations involving the presentation of spatial information, which was always paired with operational whenever it appeared: (1) presented in text or picture with the opposite mode empty; (2) presented opposite contextual information alone; and (3) presented opposite contextual and operational information together. The effects of the mode of presenting the spatial information were the same, regardless of the combination in which it appeared. Groups receiving spatial information in text performed the assembly with fewer errors, and those seeing the spatial information in

pictures completed the tasks in considerably less time. This trade-off in benefits has important educational implications in many areas, such as the design of instructional materials for tasks in which either speed or accuracy of execution is the principle consideration. It may be the case that designers of instructions for many tasks may want to employ differential modes of presentation depending on the relative importance of speed or accuracy in a particular subassembly. For example, in technical assembly or repair manuals, the overall emphasis might be on speed of assembly, in which case the spatial information should be placed primarily in pictures. However, there may be certain critical subassemblies in which accuracy is an overriding concern. The instructional materials for such procedures may employ a textual statement of spatial information in order to optimize for accuracy.

The differential use of text and pictures for conveying certain categories of information depending on the content of a particular subassembly became of interest during examination of those cases where spatial and contextual information appeared opposite each other. The effects of spatial and contextual information appearing together will be discussed below.

Spatial information with contextual information. There were four instructional conditions in which spatial as well as contextual information appeared; conditions $T(O + S)P(C)$, $T(O + S)P(O + C)$, $T(C)P(O + S)$, $T(O + C)P(O + S)$. In light of the finding that both spatial and contextual information decreased the amount of time spent in performing the assemblies, a question arose regarding the net effect when they appeared together, but in opposite modes. In other words, which category of information would have a stronger effect, spatial or contextual?

Initial examination of the performance data for both tasks suggested that the effect for spatial information was stronger than that for contextual information. The assembly times in both pairs of instructional conditions were faster

when spatial information was presented pictorially. This was true in both the hand truck assembly (506.9 seconds versus 902.2 seconds, and 505.4 seconds versus 901.7 seconds) and for the felt task assembly (484.6 seconds versus 805.8 seconds, and 486.1 seconds versus 799.7 seconds). Once again, however, the story is not quite that simple.

In preparing materials for this research, a distinction was made regarding the various levels of contextual information, and a decision was made to manipulate only the most global level of contextual information. It was hypothesized that this global context would be of most help during those subassemblies to which it was nearest in the hierarchy depicted in Figure 3. If this hypothesis were

Insert Figure 3 about here

true, then it is conceivable that the strength of the effect of presenting context in different modes would be magnified in those subassemblies. These top level subassemblies were identified as steps 7 and 8 of the felt task (i.e., installation and attachment of the grommets, and installation and attachment of the yarn hanger), and steps 3, 7, and 13 (i.e., construction of the back, connection of the base to the back, and installation of the handles) of the hand truck. (Note: The wheel/axle assembly, which was originally conceptualized as a top level subassembly, was actually embedded in several lower-level steps.)

The mean assembly times for each of these subassemblies, as well as the mean total assembly time for each of the spatial and contextual conditions, is shown in the Table. Comparison of these means reveals that, although the effect of mode of presentation was stronger for spatial information than for contextual information overall, the strength of that effect was reversed for higher-level

subassemblies, where the influence of global context was predicted to be greater. This trend suggests that the effect of the mode of presentation of at least these two categories of information is the product of the interaction of several factors, including the degree of specificity of the information and the level of the particular procedure.

Insert Table about here

In summary, there was little effect on performance of variations in the mode of presentation of operational information. Performance times were reduced when spatial and/or contextual information were presented pictorially. Accuracy of performance was improved slightly when spatial information was presented textually. And, finally, the effect of pictorial depiction was greater for spatial information than for contextual information, except in high-level subassemblies, where the effect of pictorial depiction of contextual information suppressed the presentation effect of spatial information.

These findings have some obvious practical implications for the preparation and use of instructional materials. As was discussed earlier, in situations where speed of execution is the primary consideration, pictorial depictions of spatial and/or contextual information might be advisable; and, in those situations where accuracy of performance is essential, spatial information might be presented in text. One might be tempted to ask why materials shouldn't be developed that are fully redundant across modes in spatial information, in order to maximize both speed and accuracy. Although in principle this may be the obvious course of action, in actuality there are other constraints which often limit the amount of information that can be given. Some of these constraints may be economic in that redundant materials are more expensive to prepare than materials

using only one mode or the other. If the benefit of full redundancy is small, compared to the cost of preparing such materials, one would be left with the choice of choosing modes. As was discussed earlier, there are often situations in which space is a constraint. Instructions must frequently be kept brief and preparers of such materials are generally seeking the form which will provide the most useful information in the smallest space. Finally, the evidence regarding the benefits of redundancy has not been thoroughly demonstrated. In this study, the effect of redundancy was not the focus of investigation, but might be a worthwhile domain for future research.

The fact that contextual and spatial information seem to affect performance in a similar manner suggests that they may have some common attributes. As was mentioned earlier, a large part of what we mean by contextual information is general spatial and temporal information. When this information is fairly distant from a particular subassembly (according to a hierarchy such as that shown in Figure 3), the nature of the spatial information that it conveys is too general to be helpful. However, when the subassembly in question is closer to the level of contextual information, the degree of relevant spatial detail is enhanced and the context acts as spatial information. If this is the case, then the findings of this experiment can be discussed, more generally, in terms of the attributes of spatial information that might cause the differential effects observed here. One initial hypothesis might be that the amount of time spent encoding spatial information in the text is greater than that spent encoding pictorially depicted spatial information. This notion can be rejected when one realizes that actual reading times, although not precisely measured, range from about 8 seconds per subassembly to about 20 seconds per subassembly. For the hand truck task, if the reading times were accumulated over all 13 subassemblies, the range of total reading times would be about 100 seconds to 260 seconds. Performance times ranged from 428 seconds to 2,395 seconds. The difference in

performance times is in all likelihood due to factors other than reading (i.e., encoding) time alone.

A second hypothesis regarding this effect involves the degree of abstraction of the two modes of presentation. Since textual representations are more abstract than pictorial representations of objects, a reader of text may require more time, first to construct a mental image of the object, and then obtain the relevant information, whereas the "reader" of pictures is provided with the image and is able to proceed directly to obtaining the information. If this hypothesis is correct, then the added processing time for reading of the text may also account for the smaller number of errors. If an increase in the amount of processing time can induce a greater "depth" of processing by instigating more manipulations of the mental image, additional relevant information may emerge about the objects, the spatial relationships among them, and the operations that can be used upon them. Such inferred information may result in the reader producing fewer errors than the readers of the more quickly, but less deeply processed pictorial depiction. The tasks used in these studies may have been more "spatial" in their composition thus enhancing the effect of mode of presentation for spatial information. This hypothesis is compatible with the results of this research but would require considerably more investigation before it could be accepted.

The results of this study points to certain effects on performance as the mode of presentation of several categories of information was varied. These findings raise some important questions for theoretical considerations of text and/or picture perception and comprehension. For example, what is it about pictorial presentation of contextual and spatial information that enables readers to perform the assembly tasks in less time than readers of textual presentations of the same information? And, what is it about

textual presentation of spatial information that reduces the number of errors in these assemblies? These are questions involving many complex variables about the attention, processing, integration, and storage of information. This research has merely begun to address some of these important issues, but has provided some tools which, it is hoped, will be useful in future investigations.

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FOOTNOTE

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TEXT

	Nothing	Operational	Contextual	Operational and Spatial	Operational and Contextual
Nothing	---	1188.40 sec. 22.90	---	1194.40 sec. 0.70	1099.60 sec. 17.10
Operational	1193.90 sec. 22.50	---	1105.00 sec. 14.60	---	---
Contextual	---	803.50 sec. 15.00	---	902.20 sec. 0.20	---
Operational and Spatial	709.50 sec. 1.40	---	506.90 sec. 0.80	---	505.40 sec. 0.80
Operational and Contextual	807.50 sec. 14.30	---	---	901.70 sec. 0.20	---

Figure 1. Mean Assembly Times (in seconds) and Mean Number of Errors for the Model Hand Truck Task

TEXT

		Nothing	Operational	Contextual	Operational and Spatial	Operational and Contextual
P I C T U R E	Nothing	---	849.40 sec. 19.00	---	1331.20 sec. 1.30	877.20 sec. 14.90
	Operational	836.10 sec. 19.30	---	875.80 sec. 14.90	---	---
	Contextual	---	655.70 sec. 13.60	---	805.80 sec. 0.10	---
	Operational and Spatial	717.40 sec. 1.30	---	484.60 sec. 1.20	---	486.10 sec. 1.20
	Operational and Contextual	645.20 sec. 13.30	---	---	799.70 sec. 0.20	---

Figure 2. Mean Assembly Times (in seconds) and Mean Number of Errors for the Felt Wall Hanging Task

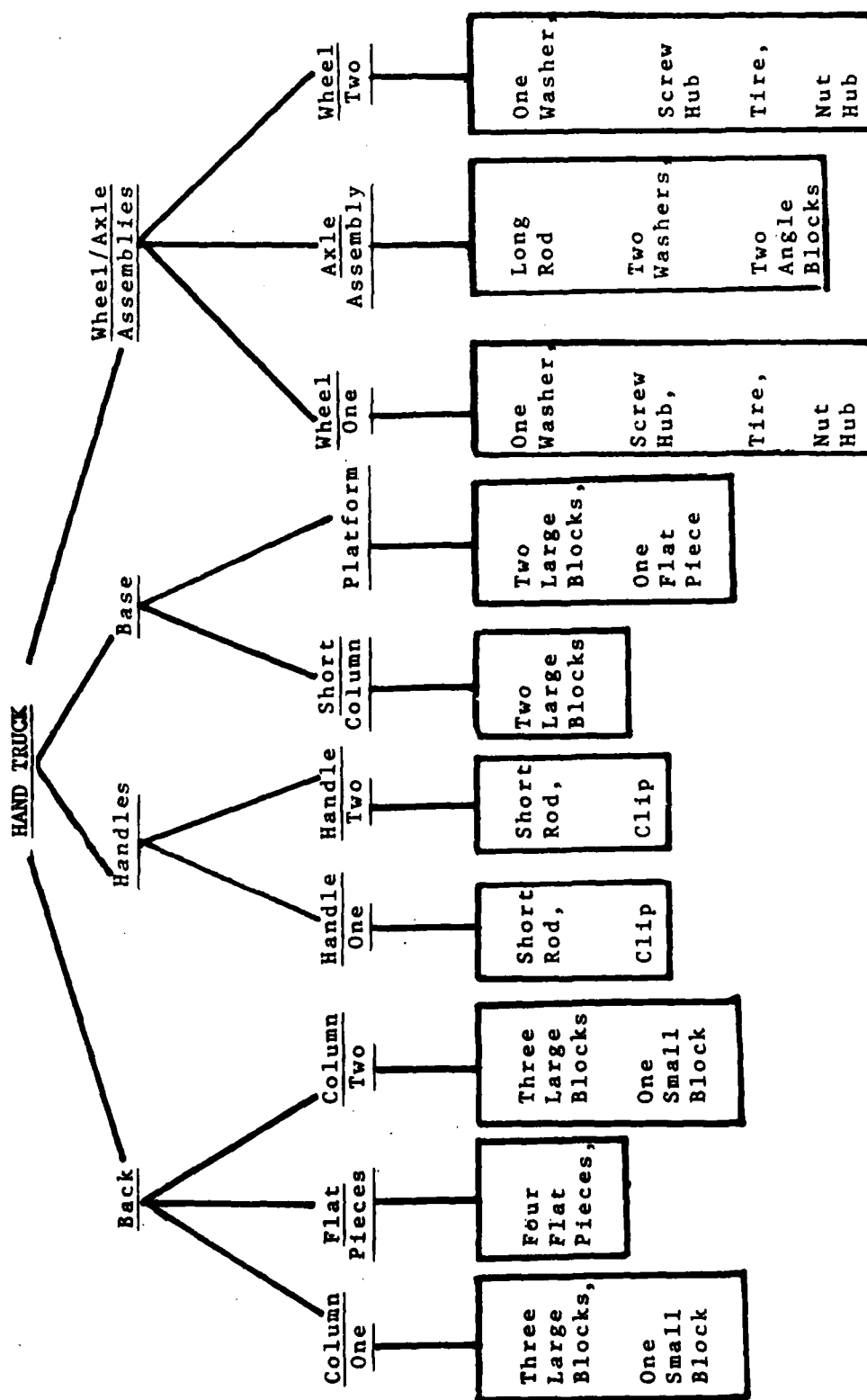


Figure 3. Hierarchy of Subassemblies for the Hand Truck Construction

Table

Mean Assembly Times for Spatial/Contextual Comparisons

	Condition T(C)P(O+S)	Condition T(O+S)P(C)	Condition T(O+S)P(O+C)	Condition T(O+C)P(O+S)
Felt Task:				
Step 7	83.60	45.90	45.80	77.30
Step 8	60.80	30.50	30.80	58.70
Overall	484.60	805.80	799.70	486.10
Hand Truck Task:				
Step 3	92.70	82.90	64.80	97.90
Step 7	162.80	89.60	100.90	117.40
Step 13	78.10	57.70	58.80	67.10
Overall	506.90	902.20	901.70	505.40

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