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Object Access in Mental Models under Different Perspectives Induced by Linguistic Expressions

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Object Access in Mental Models under Different Perspectives Induced by Linguistic Expressions

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A mental model of a text should allow for access to objects distributed spatially, according to the text. An experiment was conducted to test three hypotheses about the representation of spatial relations between a recipient of texts and the objects mentioned. Subjects read stories about a protagonist situated in a room, describing several objects in specified spatial relations to the protagonist. After each story the subjects decided on two objects whether these were mentioned in the text (target) or not (distractor).

First hypothesis: The latency of target verification depends on the spatial relation between the protagonist and the object. Objects in front of the protagonist should be verified faster than those beside and behind him. If objects beside or behind the protagonist are verified faster in a recognition task, it should allow one to decide between one of two alternative models: the spatial framework model (objects beside are slowest) and the model of mental transformation (objects behind are slowest). The results corresponded to the latter. This seems to suggest that the access to mentioned objects depends on a mental model of the situation which is transformed analogous to a perceptual representation.

Second hypothesis: If the protagonist changes his orientation, according to the text, the previous relations will be rotated. After the answer to the first test object the story was continued and a new orientation of the protagonist was mentioned. The verification latency of the second test object was determined definitely by the new orientation. This result supports an access to objects via a mental model.

Third hypothesis: 'Experiencer' verbs (e.g., "Peter sees the wardrobe.") are more likely to induce the perspective of the protagonist than 'agent' verbs (e. g., "Peter looks at the wardrobe."). The latter version should support an external perspective of the recipient. A systematic structure in latencies of object verification will be found only under the protagonist's perspective. In case of an external perspective, response times should be about equal for all positions of objects. The response times confirmed these hypotheses. Finally, the categories 'experiencer verbs' and 'agent verbs' proved to induce different perspectives, according to the hypothesis.

1. Introduction

The present research has been done within an interdisciplinary research project at the Technical University of Berlin, named "Cognition & Context" ("Kognition & Kontext"; K&K). The research project is intended to establish close cooperation of psychology, linguistics, computer science, and artificial intelligence under the common topic 'Perspective in Language Comprehension' Here perspective is understood as a context factor in interpreting linguistic expressions. Up to now, research has concentrated on the influence of the perspective adopted by the recipient of a text. Perspective, as conceived here, has to be understood in a narrower, more verbatim sense, analogous to the perspective of a percipient.

Our investigation of processing discourse is based on the following fundamental assumptions:

In understanding a text (about spatial configurations), a reader constructs a mental model of the situation described by the text. Remembering a text demands access to the respective mental model. Therefore, retrieval processes reflect properties of the underlying representation, i.e., the mental model.

A mental model based on a description of spatial configurations reflects properties analogous to spatial properties. Moreover, a mental model is in perspective, i.e., the space-analogous properties vary with the perspective the reader takes on the described situation.

Linguistic expressions have an impact on the perspective that readers take on the described situation, i.e., linguistic expressions induce perspective.

2. Theoretical Presumptions

2.1 Spatial relations in mental models

Bransford, Barclay, & Franks (1972) found that readers, encoding spatial descriptions, automatically infer relations not explicitly mentioned in the text. They concluded that comprehension has to be characterized not as a (purely) interpretative, but as a constructive process. The recipient exploits the linguistic input to construe a semantic description of the situation depicted by the text. This insight provides the basis for the concept of mental models in the theory of discourse comprehension. According to van Dijk & Kintsch (1983), the recipient constructs a representation of the situation itself on the basis of a propositional-semantic discourse representation. The construction of a 'situation model' marks the momentary goal in comprehending discourse. The concept of mental models (e.g., Johnson-Laird, 1980, 1983; Garnham, 1981) extends these assumptions so that the reader now not only constructs a (propositional) *description of the situation*, but a (non-propositional) *representation of the situation itself*. Accordingly, mental models are postulated to sustain space-analogous properties, thus supporting specific processes of inference and retrieval. Thus psychology gains a common subject of interest with artificial intelligence, where qualitative spatial reasoning recently received broad attention.

According to Glasgow & Papadias (1992), mental models are represented in working memory (see also van Dijk & Kintsch, 1983; Glenberg & Langston, 1992; Logie & Baddeley, 1990). Here, we are not concerned with the question of translating a mental model in a long term memory representation (*descriptive representation*) or how such a representation is used to reconstruct a mental model for retrieval. Similar to Kosslyn (1987), Glasgow & Papadias (1992) distinguish between a spatial and a visual representation in working memory, a distinction which is based on empirical evidence. For the spatial representation, they claim: *"The spatial representation of an image denotes the image components symbolically and preserves relevant spatial properties."* The visual format, on the other hand, conveys information concerning form and size: *"The visual representation depicts the space occupied by an image as an occupancy array. It can be used to retrieve information such as shape, relative distance, and relative size."* (Glasgow & Papadias, 1992, p. 356). Within the present topic, we concentrate on the qualitative-spatial representation of

object relations, and neglect their visual representation.

The most convincing support, that mental models bear space-analogous properties, stems from revealing distance effects. Numerous findings show, that objects described as being localized close to each other are represented close to each other (e.g. Morrow, Greenspan, & Bower, 1987; Morrow, Bower, & Greenspan, 1989; Glenberg, Meyer, & Lindem, 1987, Kaup, 1994, Wender & Wagener, 1990; Wagener-Wender & Wender, 1990).

The present research is more closely related to the work by Franklin & Tversky (1990), dealing with the access of objects in mental models dependent on their position relative to a recipient. The recipient had to imagine himself in a described situation. Franklin & Tversky used the following paradigm: Subjects read texts, describing the recipient in specific situations. Objects were located in various positions relative to the recipients (*head, feet, front, back, right,* or *left*)[1]. The critical task of the subjects was to respond to a probed spatial relation by reproducing the corresponding object, while response time was measured. Franklin & Tversky discuss three theoretical alternatives, how response times may vary as a function of the probed relation:

(1) The **equiavailability model** predicts no influence of the kind of probed relation on response times. A given object is equally accessible at each of the positions in question.

(2) The **model of mental transformation** or **rotation** leans on perception: the recipient is directed (in the mental model) towards the object in front of him. These objects are accessed directly. Other relations require the recipient to mentally rotate towards the probed direction. Mental rotation is conceptualized in analogy to the mental rotation of objects as described by Shepard & Metzler (1971). Accordingly, questions referring to *head, feet, right,* or *left* lead to slower response times than to *front*, because they all require a rotation of 90˚. A rotation to the back of 180˚ results in a still further increase in response time.

(3) The **spatial framework model** presumes, that humans structure their environments according to three dimensions. These dimensions are extensions of the body axes: one vertical and two horizontal axes. Since the vertical *above/below* dimension is invariant with respect to most body movements, it should be the most important one for orienting in space. Also, this model stresses the coincidence of the vertical axis with gravity, i.e., the correspondence of the referential system of the body with the physical system in the case of the canonical position (upright). The *left/right* dimension is defined relative to the *front/back* dimension, i.e., it is derived from this, and thus predominated by it. Because the *front/back* dimension is perceptually and functionally asymmetric, *front* dominates *back* on this axis.

In sum, the spatial framework model, which was developed from a linguistic background, leads to the following hypotheses derived from dominance relations between the three dimensions: Questions concerning the *ahead/below* dimension are responded to fastest, because this dimension is the principle one for orienting in space. Questions concerning the

[1] These expressions, called 'egocentric' by the authors, have been used in all but the first experiment. In the first experiment they used the expressions *above, below, right of, left of, ahead of* and *behind*. With respect to the egocentric expressions, the authors report that the intended meaning was explained to the subjects.

left/right axis are responded to slowest because this axis is predominated by the *front/back* axis, thus prompting responses least. The *front/back* axis leads to intermediate response times and its asymmetry leads to faster responses for *front* than for *back*.

The predictions derived from the spatial framework model rely essentially on the dominance relations between the three axes. While the asymmetry of the *front/back* dimension is considered, the obvious asymmetry of the *above/below* dimension in the human reference system is not taken into account. Furthermore, Franklin & Tversky disregard the possibility that the symmetry of the *left/right* axis leads to difficulties in discerning the intended pole on this axis. In interpreting a relational expression, not only the relevant dimension but also the intended pole needs to be identified. The faster access to objects on both asymmetric dimensions might also be attributed to a greater difficulty of discerning the poles on the symmetric *left/right* dimension.

The data presented by Franklin & Tversky consistently support the spatial framework model and are not compatible with the predictions of the model of mental transformation. Specifically, objects behind the recipient were more readily accessed than those to his left or right. Nevertheless, the role that the spatial framework model plays in these authors' task does not seem to be specified in the end. In presenting the spatial framework model, Franklin & Tversky (1990, p. 64) state: *"Our task, however, entails not just imagining locations in space and examining their contents but also* ***comprehending the spatial language*** *needed to construct the spatial mental model and* ***to identify the probed directions****."* (emphasis by the authors). They continue: *"What follows is an analysis of a spatial framework, which readers are hypothesized to construct* ***in order to comprehend the*** *descriptions and* ***questions****."* (emphasis by the authors). These statements suggest that the spatial framework model predicts differences in encoding linguistic expressions of spatial relations, especially those that were used in probing directions. The time needed for encoding these prompts starts with the presentation of the critical item, and ends with the initialization of the access to the object in this position in the mental model. The time measured by Franklin & Tversky merges the time needed to encode the relational expression with the time needed to access the relevant object[2]. If the encoding of the critical expression varies according to the spatial framework model while pure access time remains invariant, like predicted by the equiavailability model, one would get exactly the results reported by Franklin & Tversky. Given a strong effect for encoding, object access could even not be said to contradict the model of mental transformation. The data do not allow to decide whether they are attributable to encoding processes, called here the **encoding hypothesis**, or to object access. Franklin & Tversky maintain that their results reflect characteristics of object access.

Discussing the understanding of spatial expressions, Clark (1973) suggested a *comprehension hypothesis*, which is related to our encoding hypothesis. According to Clark (1973, p. 57), *"the less complex of two expressions, as defined by the complexity hypothesis, should be comprehended more quickly than the other."*. Since Clark concentrates on dimensional adjectives and states complexity in terms of markedness and semantic features, both hypotheses are not completely congruent.

[2] The time needed to generate the answer can be neglected in the present context.

Franklin & Tversky are aware of the fact that their results might be explained in terms of comprehension, i.e., encoding, but they reject it. They argue that different linguistic expressions (see ftn. 1) lead to identical results. This argument has to be dismissed: The encoding hypothesis refers to the spatial concepts expressed, and not to the expressions themselves. Therefore, if two different expressions name the same underlying concept they will yield the same result.

Franklin & Tversky point out, that the spatial framework model makes deviant predictions in the case of a recipient who imagines himself in a reclining position. The deviation results from the fact, that for a reclined person, the vertical axis no longer coincides with gravity. However, we do not accept this as an argument against the encoding hypothesis. As the above mentioned statements of Franklin & Tversky show, the spatial framework model refers to the comprehension of spatial language. If the spatial framework model leads to deviant predictions in the case of a reclining person, these predictions should be related to the encoding specifities of spatial expressions, which are ambiguous for reclining subjects. The reclining position resulted in a general increase in response times, indicating a general interference effect. May & Wartenberg (1995) developed a model of interference in connection with imagined rotations and translations in order to explain the advantage of actually executed re-orientations in contrast to imagined ones. According to these authors, two subjective spatial representations exist[3]: one of the body and the other of the surrounding environment. An interference is to be expected if both representations do not coincide. In the present context, this interference needs further examination.

Considering the impact of a subject's orientation on the use of expressions of spatial relations, Levelt (1986, p. 203) put forward the *principle of canonical orientation*. It states, that reference to an intrinsic dimension of an object within the intrinsic system requires that this dimension is congruent with the canonical position of the object. The reference object in the experiments of Franklin & Tversky was the recipient himself and the reclining position is not his canonical orientation. Since Levelt points out that expressions of intrinsic spatial relations only correctly apply to reference objects in canonical positions, an interference in the case of a reclining position should be expected. According to our view, Levelt's principle provides a good explanation for the general interference in the case of the reclining position. Since Levelt introduced his principle to interpret the use of linguistic expressions, namely expressions of intrinsic spatial relations, we see this as further evidence against the view, that the encoding hypothesis is to be rejected on the basis of the results in question.

Franklin & Tversky (1990, p. 75) postulated far reaching conclusions in interpreting their results: *"The critical evidence is that different spatial locations are differentially accessible, a finding easier to account for in terms of the conception of space than in terms of the perception of space."*. Since they reject the encoding hypothesis, the spatial framework model has to be seen as reflecting representational properties of mental models. It is the object access which differs for different spatial relations. As a consequence, terms of the perception of space can no longer be seen as relevant in conceptualizing mental models.

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[3] In fact, May & Wartenberg (1995) distinguish between three representations, a perceptual one, a proprioceptive one, and a cognitive-transformational one. But in order to explain their results they rely on the interaction of the two representations mentioned in the text.

A final remark concerning the term 'encoding' seems to be necessary. Franklin & Tversky claim that their results reflect properties of the mental model to which they relate object access. As conceived here, encoding means the interpretation of spatial expressions in relation to the relevant mental representation. Since it has been argued that mental models are essential for comprehending discourse, encoding spatial expressions can not be seen independent of the mental model to which they relate. As a consequence, the data of Franklin & Tversky reflect properties of mental models even if the encoding hypothesis would account for their results.

We want to emphasize that we are not contradicting the spatial framework model as such. We only doubt that there exists sufficient evidence to identify the kind of processes which have to be accounted for by this model. We aimed to get further insight in object access in mental models, specifically by giving no hint where within the model the object has to be accessed. To overcome the confoundation of encoding time and access time, we initiated object access by presenting object names. Subjects decided whether the named object was part of the described situation or not.

2.2 Re-orientation in mental models

The spatial relationships in question are relations of objects relative to a protagonist. The relational expressions are ambiguous as to be interpreted intrinsically or extrinsically. However, in the context of the texts used, it seems plausible to interpret them as intrinsic expressions. An intrinsic expression states the position of an object with respect to the orientation of the relatum (Herrmann, 1990), i.e., the protagonist, which itself is linguistically expressed. In other words, the object is localized with respect to the reference frame of the relatum. Holding the positions of the objects constant, a re-orientation of the relatum has the effect that the original relationships are no longer valid, but have to be rotated. For example, if the protagonist turns to his left, the object originally placed in front of him is now to his right. There are at least two possibilities to represent such a re-orientation.

A mental model is said to represent the actual situation. As a result, at the time of encoding a re-orientation will initiate an update of the mental model, i.e., the mental model will always represent the actual valid relations.

Alternatively, a re-orientation can be represented by a structural description. In contrast to a space-analogous mental model, a structural description is a structured propositional representation of the description of a situation which allows for keeping different aspects of a situation distinct (Pinker, 1984). A structural description may represent an object configuration within the reference frame of the relatum as originally described and, in addition, provide information about a re-orientation of the relatum. If an actually valid relation is in question, the relevant information would have to be inferred at test time. The object access as such, as in the case of a recognition task, would be independent of the fact, that a re-orientation of the relatum has taken place. Therefore, differences in object access would reveal to be dependent on the original described configuration, not on the actual configuration.

If objects are accessed within a mental model in the present sense, differences in reaction

times will depend on the actual situation, i.e., on the spatial relations which hold at test time. If, in contrast, reaction times show to vary dependent on the originally described relations, even after a re-orientation of the relatum was mentioned, one could no longer assume an underlying mental model. In the last case, properties of the description rather than properties of the situation described would be relevant. This would require an explanation in terms of a structural description. Since one of our basic assumptions claimed that object access proceeds on mental models, we expect reaction time patterns in accordance with the properties of the actual situation. Franklin & Tversky (1990) report that reaction time differences after mental re-orientations indeed depended on spatial relations valid at the time of testing. In accordance with our claim, these authors take the results as evidence for an underlying mental model.

2.3 Perspective in mental models

In the case of a text about a spatial configuration with one protagonist, the recipient can take one of at least two possible perspectives in the described scene:

(i) The recipient can take the perspective of the protagonist. The standpoint of the recipient is anchored within the described situation in accordance with that of the protagonist. Moreover, the perspective of the recipient is directed within the scene in a specified way: his orientation corresponds to that of the protagonist. A perspective of the recipient characterized this way we call a **protagonist's perspective**.

(ii) The recipient can take a standpoint external to the described situation, i.e., his standpoint is not anchored within the scene. In fact our claim is, that under such a perspective, there exists no specified spatial relation between the recipient and the described situation. Under these circumstances, the orientation of the recipient is not determined by spatial properties of the situation, including the orientation of the protagonist. Spatial properties do not predict the focus on the mental model. This kind of perspective we call **external perspective**.

The model of mental transformation and the spatial framework model work on different assumptions of the recipient's relation to a given scene. We expect reaction times to vary systematically between object positions only for recipients taking a protagonist's perspective. For recipients taking an external perspective, we expect reaction times not to systematically differ dependent on the object's position. Instead, reaction time patterns should fit the equiavailability model (see above). That is not to say, that under an external perspective recipients do not focus within the mental model, but such a focus should not be determined by spatial properties of the described situation, such as object relations.

For instance, Bryant, Franklin, & Tversky (1992) investigated the influence of the recipient's perspective. They distinguished between an internal and an external perspective. With respect to the internal perspective, comparable to our protagonist's perspective, they refer to the spatial framework model. For the external perspective, Bryant et al. claim that response time patterns correspond to those of the internal perspective with one exception: since the asymmetry of the *front/back* axis under an external perspective loses its perceptual and functional significance, they predict no difference between *front* and *back*. In contrast to the earlier "internal" spatial framework model, they call this model the "external spatial framework"

It may surprise that the predictions of Bryant et al. dissent from our own predictions for the same case, but this difference is due to a terminological divergence. Bryant et al. speak of an external perspective just if the standpoint of the protagonist (and accordingly, of the recipient) is located not within the object configuration, but as facing it from outside. The recipient is oriented towards the whole scene. According to our view, the terms 'internal perspective' and 'external perspective' of Bryant et al. are puzzling because the perspective of the recipient is the same in both cases: the standpoint of the recipient is spatially specified with respect to the described situation and in both cases he is oriented in specified ways. The internal as well as the external perspective of Bryant et al. can be characterized as a protagonist's perspective in our terms. These 'perspectives' only differ in the fact that for the 'internal perspective' the position of the recipient is located within the described configuration, while for the 'external perspective', it is located outside of the described scene. In both cases the standpoint of the recipient is spatially specified.

Our concept of different perspectives corresponds more closely to that discussed by Franklin, Tversky, & Coon (1992) in a study of texts which do not allow for a consistent protagonist's perspective, e.g., by introducing a second main character. Except for the possibility, that in such cases recipients construct two models simultaneously for both actors, Franklin et al. consider two alternatives: The recipient might take an **overview** (or oblique) **perspective**, resulting in a mental model of the situation with both protagonists. Alternatively, the recipient might construct a representation, bearing **no perspective** at all. For the latter case, the authors refer to a structural description, which is not visualisable, but which gets visualisable when a specific perspective on the situation is adopted. For both alternatives, overview perspective and no perspective, Franklin et al. posit equiavailability. As a possible deviation, they consider **weak equiavailability**. With Cooper & Shepard (1975) and Parsons (1987a, b), they propose, that responses to *left/right* questions require an internal perspective, and its adoption leads to slower response times on this dimension. If one assumes the three axes as equally accessible, but stresses the greater difficulty in discerning *left* and *right*, because of the symmetry of the *left/right* dimension, as discussed above (p. 4), one arrives at the same conclusions, i.e., weak equiavailability. Franklin et al. report results some of which fit to the equiavailability hypothesis and some to the assumption of weak equiavailability.

The concept of perspective is not unequivocally defined in the contribution of Fanklin et al., but we tend to disagree with it in the following aspects: Taking the term 'overview perspective' verbatim, a spatial relation between recipient and the situation is specified. The recipient 'looks' at the scene from above. If the overview perspective is to be understood in this sense, it is not compatible with our external perspective, postulating no specified spatial relation between recipient and situation. Regarding the case of 'no perspective', Franklin et al. state that such a representation might be visualized by adopting a specific perspective. We suggested that arguments referring to visualization might be dispensed here according to the distinction of visual and spatial representation. Since questions concerning spatial relations can be answered on the basis of spatial representation only, there is no need to recur to visual representation formats. Bryant, Franklin & Tversky (1992) equate the perspective-free representation with a structural description as a special kind of a mental model. But structural description does not bear the dynamic characteristics of a mental model. Within the spatial framework model the relations of variable perspectives to preset structures, and of

visual to spatial representation remain open questions.

2.4 Induction of perspective in mental models

Franklin et al. (1992) investigated the effect of properties of a described situation on the perspective adopted by recipients (e.g., by introducing two protagonists). We are interested in influencing the perspective taken by recipients by using different linguistic expressions, while keeping the described situation as invariant as possible. In doing this, we concentrate on verbs expressing the visual and/or physical orientation of the protagonist. A first hypothesis, which stated that verbs of perception induce a protagonist's perspective, while verbs of motion induce an external perspective, had to be rejected. A modified hypothesis claims, that the thematic role that the subject inherits from the verb, that is responsible for the perspective the recipient will take, namely the contrast of *agent role* and *experiencer role*[4]. While, according to our former hypothesis, the verbs 'to go to' ('gehen zu') and 'to look at' ('sehen zu') fell in different categories, they now both are categorized as *agent* verbs. In contrast, the verb of perception 'to $see_{trans.}$' ('$sehen_{trans.}$') is an *experiencer* verb[5]. A verb which supplies the thematic role *experiencer* to the subject, i.e., the protagonist, is taken to induce the protagonist's perspective, while a verb providing the thematic role *agent* to the protagonist should induce an external perspective. An *experiencer* verb focuses on the experienced object, i.e. on the object of the perceiving protagonist's act. In contrast, an *agent* verb in the first place addresses the relation between the intentional agent and the object towards which he acts, i.e., an *agent* verb focuses on the act itself, which is a relation between agent and theme. In the spirit of this distinction, an *experiencer* verb presupposes the perspective of the percipient while an agent verb directly addresses the subject as part of the event. In contrasting the verbs 'to look at' and 'to $see_{trans.}$' it is worth mentioning that a sentence like (I) expresses an observable state of affairs while (II) does not. Only Peter himself could truthfully assert the following sentence (II).

(I) Peter looks at the wardrobe.
(II) Peter sees the wardrobe.

Which of the two features, thematic role or observability, marks the contrast of interest, is not yet quite clear.

An alternative suggestion, leading to opposite predictions, concerns the intentionality of the

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[4] As a linguistic criterion to identify the thematic role the subject inherits from the verb, we take the "in order to" test of Gruber (see Gruber, 1967). If the verb satisfies the test, the subject is taken to be the agent:

(Ia) Peter looks at the wardrobe in order to inspect its content.
(IIa) *Peter sees the wardrobe in order to inspect its content.

Likewise, other than verbs of perception can be tested:

(IIIa) Peter goes to the wardrobe in order to inspect its content.

[5] The contrast of the German analogues of these verbs is even more interesting: 'to look at' and 'to $see_{trans.}$' are expressed by the very same verb: 'sehen zu' and '$sehen_{trans.}$', and the prepositions taken by the *agent* verbs are the same too 'gehen zu' (to go to) and 'sehen zu' (to look at).

agent. The verb argument, which inherits the thematic role *agent* from the verb, is characterized by its intentionality (e.g., see Dowty, 1991). Thus one could argue, that an agent verb makes the perspective of the agent more explicit by stressing his intentionality. Since intentionality has to be understood in terms of 'directed towards an object / a goal', the previous considerations seem more plausible. But finally, this remains an empirical question.

3. Empirical test

3.1 Experimental design

Object access in mental models was experimentally tested as a function of (1) **object position** relative to a protagonist, (2) the **orientation** of the protagonist at test time, and (3) the **perspective** taken by the recipient. Subjects read 18 stories about a protagonist surrounded by objects and were tested by two critical items per story. Each critical item identified an object, which had to be appraised on being part of the described situation (target) or not (distractor) by pressing respective keys. The dependent variable was verification time, i.e., the time from the beginning of the target presentation until the subject's *yes*-reaction. The experiment was based on a three-factor design, constituted by the factors *OBJECT-POSITION*, *ORIENTATION* and *PERSPECTIVE*.

3.1.1 *OBJECT-POSITION*: within-factor with three conditions

Each story mentioned three critical objects with one of them located in front of, beside, and behind the protagonist. In case of 'beside' the positions 'left' and 'right' were alternated. To avoid a confounding of the object position with the order of mentioning, the sequence of mentioning was randomised. It should be kept in mind that the labels 'front', 'beside', and 'behind' always refer to the originally described object positions, which not necessarily coincide with the positions valid at test time.

3.1.2 *ORIENTATION*: within-factor with two conditions

In every story, two critical items were presented. An *orientation sentence* indicating the protagonist's momentary orientation preceded the first critical item. This sentence always mentioned the protagonist's orientation in accordance with the original description of the object configuration, i.e., the protagonist was directed towards the object in front. After the response to the first item, the second *orientation sentence* followed, always expressing a re-orientation of the protagonist by 90˚. I.e. the protagonist was always mentioned to be directed towards the object originally beside him before the second test item was presented. In this second test, the label 'beside' refers to the object now in front of the protagonist, while the labels 'front' and 'back' refer to the objects to his left and right. No object was located 'behind' the protagonist after this reorientation had taken place.

3.1.3 *PERSPECTIVE (VERB)*: between-factor with two (three) conditions

The orientation sentences (OS) expressed the protagonist's momentary orientation through verbs expected to induce perspective:

(OS) He looks at / goes to / sees the wardrobe.

To strengthen the impact of the specific verbs on perspective, the use of verbs was held constant within subjects. The agent verbs 'to go to' and 'to look at' were expected to induce an external perspective. The experiencer verb 'to $see_{trans.}$' was expected to induce the protagonist's perspective. Since this factor realizes induced perspective rather than verb, the factor comprises two conditions.

Figure 1: Experimental 3-factor design with the between-factor *PERSPECTIVE* (3 verbs; 2 perspectives), the within-factor *ORIENTATION* (2 conditions), and the within-factor *OBJECT-POSITION* (3 conditions). The number of repeated measures within each cell varied.

ORIENTATION of the protagonist		original orientation			re-oriented by 90°		
	OBJECT-POSITION	front	beside	behind	front	beside	behind
Verb or induced **PERSPECTIVE**	'to go to' (external) n=14						
	'to look at' (external) n=13						
	'to see_{trans}' (protagonist's) n=13						

3.2 Hypotheses

For subjects keeping an external perspective ('to go to' and 'to look at'), object access should exhibit no systematic time differences as a function of object position (*equiavailability*). For the condition *external perspective*, neither a main effect of the factor *OBJECT-POSITION*, nor a significant interaction with the factor *ORIENTATION* was expected on verification times. Since the zero hypothesis is maintained, the groups realizing the external perspective serve as control groups within this design.

For subjects taking the protagonist's perspective, verification times were expected either to correspond to the spatial framework model or to the model of mental transformation. Both models predict the fastest access to objects in front[6], but differ with respect to objects beside and behind. According to the spatial framework model, objects behind are more easily accessed than objects beside, and should be verified faster. The model of mental transformation predicts the opposite: objects beside are accessed more quickly than objects behind. As we argued above, the available evidence does not allow for a final decision for one of the competing models. Consequently, we do not put forward a specific hypothesis on the object positions beside and behind a protagonist, but we judge faster verification time for

[6] To put it more accurate, according to the spatial framework model, objects in front are accessed fastest as compared with objects beside or behind, not as compared with objects above or below.

objects in front as a criterion for an effective protagonist's perspective.

Within the recognition paradigm, the predictions of the model of mental transformation have to be specified. Since naming of objects does not indicate any direction of access, a search of an object to the left could in principle afford a mental rotation by 270˚, e.g., if there exists a preference to rotates to the right. Accordingly, if half of the objects beside are located to the right (90˚) and half of them to the left (270˚), on the average access to an object beside would require a rotation by 180˚. As a consequence, access latencies would be equal for objects beside and objects behind, thus contradicting the model of mental transformation, despite the fact, that a rotation occurs. Since in the stories used here, an object was placed only at one of the positions beside the protagonist, we hope that subjects tend to rotate, if they rotate at all, towards the direction of occupied positions, thus yielding faster access to objects to the left as well as to the right, as compared with objects behind.

If verification times in the recognition task conform to the model of mental transformation, we count this as evidence, that the results of Franklin & Tversky (1990) have to be explained in terms of the encoding hypothesis. In contrast, if verification time patterns are in accordance with the spatial framework model, they confirm the claim of Franklin & Tversky, that there exist invariant dimensional properties of object access. If the model of spatial framework is able to account for verification time patterns also in the recognition paradigm, the encoding hypothesis has to be rejected.

Letting aside the question, which of the two alternative models may account for the results under the protagonist's perspective, verification time differences are expected to be a function of object position at test time and not of originally given descriptions. Given a protagonist's perspective, we predict an interaction of the factor *OBJECT-POSITION* with the factor *ORIENTATION*. If verification time differences turn out to depend on the originally described relations, we can not maintain that subjects operated on mental models.

The data of our experimental design should yield a significant interaction of all three factors. An analysis restricted to subjects taking the protagonist's perspective should yield an interaction of the factor *OBJECT-POSITION* with the factor *ORIENTATION*. An analysis restricted to subjects taking an external perspective should yield no effects at all.

We had no specific hypotheses on reaction times as answers to distractors nor about error rates, which were expected to be low.

3.3 Method

3.3.1 Material and procedure

Eighteen stories were constructed and presented to subjects on a computer screen. The presentation of a story consisted of six successive screen presentations (see table 1). Reading times for the presentations 1, 2, and 4 were determined by subjects, i.e., the next display was demanded by pressing a key (*self paced reading time*).

The first display introduced a protagonist, female or male, and described the surrounding

object constellation. Each object constellation was situated within a room. An anchor object together with a critical object was positioned at three of the four walls of the room. The three walls, occupied by objects, were in front of the protagonist, behind him, and to his left or right. Object position was expressed by using intrinsic expressions of spatial relations with the protagonist as relatum (see the example in table 1). Anchor objects were used later to express the orientation of the protagonist. Critical objects were used as targets in the recognition task. The descriptions were devised to support the construction of a mental model. The mentioned objects were chosen to be common and typical within the described situation. The positioning of the objects was randomized.

Table 1: Material and procedure, exemplified by the six successing presentations of the components of a story translated into English. The texts on the first, second, and fourth display had only to be read. The recognition items given by the third and fifth display had to be judged, if they had been mentioned in the foregoing description (target) or not (distractor) by pressing a key. The control question presented by the sixth display had to be answered by 'yes' or 'no', again by pressing a key. (The original German version, which was used in the experiment, is supplied as an appendix).

1.	introduction of the protagonist and description of the object constellation with anchor objects and critical objects	Torsten visits a radio station with his school class. He stands in the middle of a sound lab and watches the events happening around him with great interest. Against the wall in front of him, there is a shelf of many taperecorders. A set of earphones hangs from a hook on this box. The earphones have large soft cushions that give the impression that they would block environmental sounds completely. Against the wall to his left, there is a small metal cabinet that is filled with cabel wires. The cabel wires are of different colors and have assorted prongs for different electrical outlets. Against the wall behind him, there is a radio mixer. Somebody left their coffee cup on it. The coffee cup stands out because of its bright colors and popart design.
2.	filler sentence and 1st orientation sentence	Torsten has always been a technical enthusiast and as a result follows the explanation for every machine with much interest. He looks at the shelf.
3.	1st test item	earphones {target}
4.	filler sentence and 2nd orientation sentence	Torsten considers opening a record company later. He turns left and looks at the metal cabinet.
5.	2nd test item	turntables {distractor}
6.	control question	Is the coffee cup to Torsten's left?

The second display presented a filler sentence, referring to the protagonist, succeeded by the first orientation sentence. The orientation sentence described the protagonist as directed towards the anchor object in front of him by means of one of the three critical verbs. The verb was intended to induce perspective.

The third display presented the first test item which named either one of the three critical objects or a distractor object. Subjects had to examine the object on being part of the described situation or not (by pressing the *yes*- or the *no*-key), while reaction times were

recorded. The presentation of these test items was randomised.

The fourth display introduced a further filler sentence, followed by the second orientation sentence which expressed the protagonist's re-orientation towards the anchor object originally located beside him, using the same verb as in the second display.

The fifth display presented the second test item.

The sixth display offered a statement about a spatial relation between the protagonist and one of the six objects (critical or anchor object). The correctness of the relation was to be judged by pressing the *yes*- or *no*-key. These items were added to strengthen the subjects' readiness to build up representations of the object relations, and they served as a control. The recognition task might have been accomplished by just memorizing the three critical objects independent of their position. This case had to be excluded.

3.3.2 Subjects

Twenty-six female and fourteen male subjects between the age of 18 and 40 years participated in a 60-minutes experimental session. Thirty-four of the participants were psychology students who took part to fulfill undergraduate requirements. Six subjects were enrolled by paper advertisement and were paid DM 20,-. All subjects were native German speakers. Thirteen participants were tested under the 'to $see_{trans.}$' condition, Fourteen subjects were assigned to the 'to go to' condition, and thirteen to the 'to look at' condition.

3.4 Results: analysis of verification times

Verification times, i.e. reaction times for *yes*-responses on critical items (*hits*), were analysed. We did not evaluate *no*-responses to critical items (*misses*) and responses to distractors. Since verification times consist of both reading time and access latencies they are affected by reading time differences caused by the varying length of words. To correct for reading time differences, verification times were adjusted as follows: for each critical item, the number of letters exceeding the minimal number of letters within all test items was multiplied by 20 milliseconds. This "surplus reading time" for words longer than the shortest test item was subtracted from the recorded reaction time. The adjusted verification times were *z*-transformed for each subject to correct for differences in reading abilities. These *z*-transformed adjusted verification times underlied both the subject and item analyses. Three subjects and one item were excluded from the analyses because of missing data.

Main effect *PERSPECTIVE*

For *PERSPECTIVE*, the analyses revealed no significant differences, neither for subjects ($F(2,33)= 1.49$, $p= .24$) nor for items ($F(2,48)= 1.00$, $p= .38$). Provided that induction of perspective has been successful, this result suggests that there is no overall difference between external and protagonist's perspective in access latencies. Such a main effect was not expected, since it was not assumed that objects in mental models were altogether more accessible under one of the two perspectives.

Main effect *ORIENTATION*

No significant effect of *ORIENTATION* was found : F(1,34 respectively 49) < 1 for subject- and item-analysis. Also here, no main effect was expected. Under the second condition the protagonist always was depicted as re-oriented. But neither this circumstance nor the larger temporal distance to the introduction of objects and relations led to a general increase of the response latencies for the second test item.

Main effect *OBJECT-POSITION*

No main effect *OBJECT-POSITION* was found in the analysis for subjects (F(2,33)= 2.23, p= .12). However, the item-analysis revealed a significant effect: F(2,48)= 3.53, p= .03. The latencies did not differ for objects 'in front' and objects 'beside', but both were lower than for objects behind (see figure 2), according to univariate contrasts. Even in the subject-analysis α-error probability is about 5%:

Univariate Contrast *front* versus *beside*:
F(1,34 respectively 49) < 1 for subjects and items

Univariate Contrast *front*/*beside* versus *behind:*
F(1,34)= 3.93, p= .056 for subject; F(1,49)= 5.99, p= .018 for items

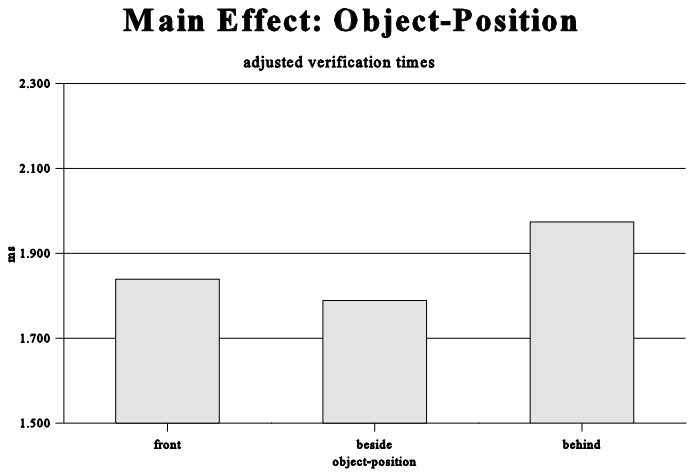

Figure 2: Averaged verification times, adjusted by number of letters, as a function of originally described object position.

Table 2: Averaged adjusted verification times as a function of originally described object position.

OBJECT-POSITION:	**front**	**beside**	**behind**
adj. VT [ms]	1839	1789	1974

Objects labelled by 'front' are, at test time, located in front of the protagonist under the first orientation but beside him under the second orientation since we kept the labels constant. The reverse is true for objects labelled 'beside'. Accordingly, objects 'behind' are behind the protagonist at times of the first test item and beside him at the second test, but never in front of him. In terms of the mental transformation-model, the 'front-' and 'beside'-items demand the same effort for rotation (on average: 45°), whereas objects 'behind' demand an averaged rotation of 135°, which should result in higher latencies. Thus, our results seem to be in accordance with the mental transformation model. However, this model applies only to the protagonist's perspective. The observed general difference in verification times deserves further discussion.

Interaction *PERSPECTIVE * OBJECT-POSITION*

No significant interaction of *PERSPECTIVE* and *OBJECT-POSITION* was found (F(4,66)= 1.36, p= .26 for subjects; F(4,96)=1.39, p= .24 for items). We expected that the main effect of *OBJECT-POSITION* could be explained as an effect of the protagonist's perspective, but this result casts doubt on this interpretation.

Interaction *PERSPECTIVE * ORIENTATION*

As expected, these two factors did not interact: F(2,33 respectively 48) < 1. This applies to the analyses over subjects and items.

Interaction *ORIENTATION * OBJECT-POSITION*

As we expected, no significant interaction was found (F(2.68 respectively 98) < 1 for both subjects and items. A significant interaction would have suggested that all subjects, under all verb conditions, would have adopted the protagonist's perspective and items. For the protagonist's perspective, verification time differences were predicted to be a function of object location at test time. Given a strong effect for the protagonist's perspective and equal access for the external perspective, an overall effect might have been possible. Such an effect was not observed. But only 13 out of 40 subjects had been intended to take the protagonist's perspective.

Interaction *PERSPECTIVE * ORIENTATION * OBJECT-POSITION*

The three way interaction of all factors reached significance for subjects but not for items:

F(4,68)= 2.88, p= .03 for subjects; F(4,98)= 1.77, p= .14 for items.

But univariate contrasts indicate a significant interaction of *PERSPECTIVE* with the combinded conditions *original orientation: 'front' / 90˚ re-oriented: 'beside'* versus *'original orientation: 'beside' / 90˚ re-oriented: 'front'* of the other two factors:

F(2,34)= 4.03, p= .03 for subjects; F(2,49)= 3.29, p= .05 for items.

The interaction between the factors *ORIENTATION* and *OBJECT-POSITION* was clearly a

consequence of the induced perspective: for a given perspective of the protagonist, always the objects positioned in front were accessed fastest. In case of the protagonist's original orientation these were objects labelled 'front', and after the protagonists' re-orientation by 90° they were labelled 'beside'. Objects labelled 'behind' were accessed slowest under both orientation conditions. For the external perspective, such a pattern of verification times was not observed (see table 3).

Table 3: Averaged adjusted verification times as a function of all three factors. For re-orientation, the actual position is given in parentheses.

		PERSPECTIVE		
		external perspective (agent-verb)		***protag. persp. (experiencer)***
ORIENTATION	***OBJECT-POSITION***	**'to go to'**	**'to look at'**	**'to see$_{trans}$'**
original orientation	**front**	1788	2039	1826
	beside	1689	1717	1991
	behind	2013	1773	2190
re-orientation by 90°	**front (beside)**	1851	1549	1975
	beside (front)	1835	1923	1581
	behind (beside)	1822	1758	2270

Separate analyses of the three subject-groups (n = 12 respectively n = 13) revealed the following: In contrast to the 'to see$_{trans}$-group, neither the 'to go to'-group nor the 'to look at'-group showed significant effects of object positions on verification times. Thus the equiavailability hypothesis could not be rejected.

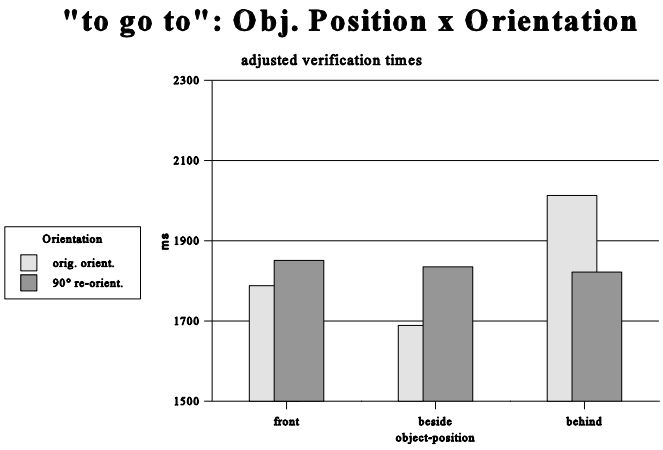

Figure 3: Averaged verification times, adjusted by number of letters, as a function of the original object position and of the orientation of the protagonist for the verb "to go to" (external perspective).

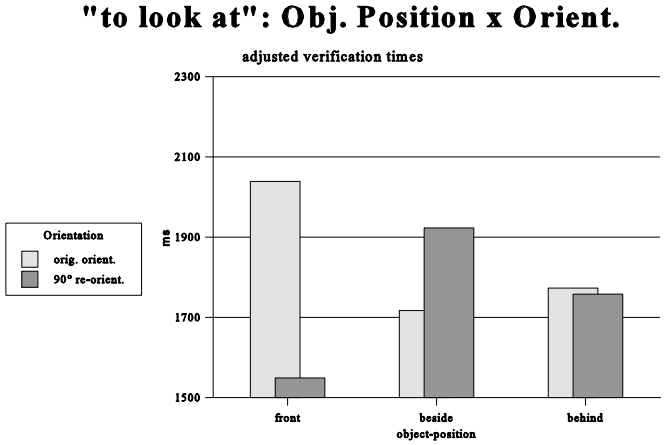

Figure 4: Averaged verification times, adjusted by number of letters, as a function of the original object position and of the orientation of the protagonist for the verb "to look at" (external perspective).

The analysis of the '$see_{trans.}$' data, despite the small sample size, revealed α-error probabilities beneath 10%. The main effect of the factor *OBJECT-POSITION* yielded an F-value of 2.60 with p= .097. The univariate contrast *front/beside* versus *behind* revealed an F-value of 4.57 with p= .056. Thus, there was a tendency to access objects in front and objects beside more quickly than objects behind. This tendency can be explained by the fact, that objects labelled 'in front' as well as the ones labelled 'beside' are located in front in half of the cases.

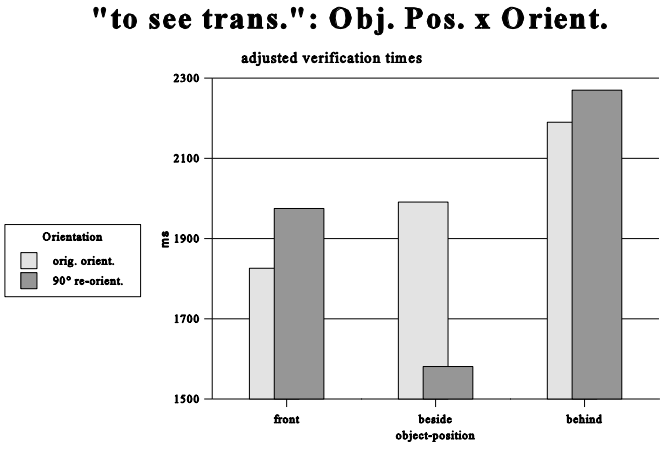

Figure 5: Averaged verification times, adjusted by number of letters, as a function of the original object position and of the orientation of the protagonist for the verb "to $see_{trans.}$" (protagonist's perspective).

Neither a multivariate nor an averaged significant interaction of the factors object-position and orientation was found, yet the univariate contrast *original orientation front/90˚ beside* versus *original orientation beside/90˚ front* yielded an F-value of 8.26 with p= .015. This suggests further evidence for our interpretation of the three way interaction of the full design. The object actually located in front of the protagonist was accessed most quickly, independent of the originally mentioned relative position. Furthermore, objects actually beside the protagonist were accessed slower than objects in front, but they could be verified faster than objects behind the protagonist. It is remarkable that objects labelled 'behind' were verified slowest even in cases where they were actually localized beside the protagonist (after his re-orientation). This fact is difficult to explain, but it gives no strong argument against the model of mental transformation.

4. Discussion

We discussed three models, implying a spatial structuring of experience, that are based on discernible assumptions. Our experiment was not designed to test one of these models. It was conceived to show that none of the existing models is robust enough to explain all empirical evidence. We concluded that three factors have to be included in a comparison of the models: the positions of objects relative to a recipient, the recipient's spatial orientation within the situation, and his perspective on or within the situation. Owing to this point of descent, our hypothesis was as well scarce as complex: We predicted only a triple interaction of all factors. This prediction was confirmed by the analysis of our data.

As dependent measure we introduced the verification time for object names, in order to avoid relational expressions for testing the representation of relations. A systematic impact of the task was observable only for subjects who seized the protagonist's perspective. Response latencies of subjects induced to take an external perspective, were not influenced by variations of object positions or orientations of the protagonist. We induced the protagonist's perspective by the verb 'to see_{trans}', and the external perspective by 'to go to' or 'to look at'. This variation of conditions was obviously successful: The recipients must have adopted the intended perspectives, since they reacted differently under both conditions.

Differences in object access depend on object positions at the time of an inquiry, as already reported by Franklin & Tversky (1990). Since the representations on which the subjects operated can be understood to have space-analogous properties we take these to be mental models in our sense. It were in fact properties of the described situation, not properties of the description of the situation, which allowed to predict the differences in object access.

With regard to object position, our investigation seems to contradict the results reported by Franklin & Tversky (1990). These authors presented data suiting the spatial framework model and contradicting the model of mental transformation. In contrast, our data are in accordance with the model of mental transformation and incompatible with the spatial framework model. The recognition task, used here to measure experimental effects, differs from Franklin's & Tversky's dependent variable in that it does not allow for an explanation in terms of the encoding hypothesis. The items initializing the access process in our task do

not refer directly to the spatial relations addressed by the spatial framework model. We discussed the encoding hypothesis as a possible explanation for the data of Franklin & Tversky, but not for our own. Here we see a possibility to harmonize the conflicting evidences. If the results of Franklin & Tversky indicate encoding differences, they would reflect properties of mental models, but in turn, properties of mental models reveal to be task-dependent. If object access is initiated without any hint as to where within the model the object will be located, the access process will operate as hypothesized by the model of mental transformation, in an analogy to a rotation in a perceptual framework.

The evidence reported by Franklin & Tversky does not seem to us sufficient for a claim as strong as theirs, namely, that mental models have to be accounted for in terms of the conception of space, rather than in terms of the perception of space. Instead, terms of the perception of space turned out to be relevant to conceptualizing mental models.

We finally note, that the body of evidence for our conclusions is still small and demands for replication.

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Appendix: German version of an example of the stories used

Table 4: Material and procedure, exemplified by the six successing presentations of the components of a story. The texts presented by the first, second, and fourth screen had only to be read. The recognition items presented by the third and fifth screen had to be judged, if they had been mentioned in the foregoing description (target) or not (distractor) by pressing a key. The control question presented by the sixth screen had to be answered by 'yes' or 'no', again by pressing a key.

1.	introduction of the protagonist and description of the object constellation with anchor objects and critical objects	Torsten besucht mit seiner Schulklasse einen Radiosender. Er steht inmitten des Tonstudios und beobachtet interessiert das Geschehen um sich herum. An der Wand vor ihm steht ein Kasten mit mehreren Rekordern, an dem an einem Haken ein moderner Kopfhörer hängt. Der Kopfhörer hat große weiche Ohrkissen, die den Eindruck machen, als würden sie Geräusche von außen vollkommen abschirmen. An der Wand links von ihm befinden sich in einem kleinen Stahlschrank zahlreiche Kabel. Die Kabel sind verschiedenfarbig und haben unterschiedliche Steckverbindungen. An der Wand hinter ihm steht ein Mischpult, auf dem jemand seine Kaffeetasse vergessen hat. Die Kaffeetasse fällt durch ihre knalligen Farben und ihr Popart-Design auf.
2.	filler sentence and 1st orientation sentence	Torsten ist seit jeher technikbegeistert und verfolgt daher die Erläuterungen zu den einzelnen Geräten mit großem Interesse. Er sieht zum Kasten.
3.	1st. test item	Kopfhörer {Target}
4.	filler sentence and 2nd orientation sentence	Torsten denkt daran, später einmal eine eigene Plattenfirma aufzumachen. Er wendet sich nach links und sieht zum Stahlschrank.
5.	2nd. test item	Plattenspieler {Distraktor}
6.	control question	Ist die Kaffeetasse links von Torsten?