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Brief article

Verb aspect and problem solving

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ABSTRACT

Verb aspect conveys the temporal flow of an action, such as whether it is on-going or complete. If language guides how situation models are to be constructed, then verb aspect could influence cognition that would use situation models, as in solving insight problems. In this study, verb aspect within the insight problem was manipulated to determine if the imperfective aspect (was accepting) or perfective aspect (accepted) influenced people's solution rates. Results revealed that solution rates for problems that depended on the way an action was being done within the problem were better when the imperfective aspect was used. For problems that did not focus on the action of the sentence, solution rates were better when the perfective aspect was used. The language used to convey problems can influence the ease which people are able to arrive at a solution.

1. Introduction

Language processing is critical for higher cognitive processes, such as comprehension, reasoning, and problem solving, in part because language processing is more than constructing representations of the words we hear or read (e.g., Graesser, Millis, & Zwaan, 1997). Rather, we process language so that we may understand the events that the language conveys. Situation models (Johnson-Laird, 1983; van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998) are the mental representations that are created to capture events described in language, and provide the basis for comprehension (e.g., Zwaan & Radvansky, 1998) and reasoning (Johnson-Laird, 1983). The success of these processes is tantamount to the creation of an adequate situation model, and language can be viewed as a set of instructions for constructing a situation model (Fauconnier, 1994; Givón, 1992, 1995; Klin, 2004; Magliano & Schliech, 2000; Morrow, 1986, 1990; Zwaan, 1999). Thus, the form and structure of the situation model should reflect the consequences of the processing instructions provided by the linguistic input.

Morphological information, such as verb aspect, plays a critical role in situation model construction because it constrains the activation of basic event schemas that are referenced by a statement (Miller & Johnson-Laird, 1976; Elman, 2009; Ferretti, Kutas, & McRae, 2007; Ferretti & Katz, 2010; Hart & Albarracín, 2009; Madden & Zwaan, 2003; Rohde, Kehler, & Elman, 2007). The present study is concerned with verb aspect, which conveys information about the time course and duration of an event or activity (e.g., Comrie, 1985; Dowty, 1977; Vendler, 1957). For the purpose of the present study, a relatively simple distinction between perfective and imperfective aspects is adopted (Comrie, 1985). The imperfective aspect conveys an incomplete event (e.g., was accepting), whereas the perfective aspect conveys a completed event (e.g., accepted).

Verb aspect aids situation model construction in three ways. First, because different aspects convey different temporal qualities of an event, they lead to the creation of different kinds of situation models. An imperfective aspect emphasizes the processes that comprise an event as being within a temporal window (e.g., "walking to the store" emphasizes the activities that comprise the event), whereas a perfective emphasizes the end-state of that

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event without a clearly defined temporal framework or window (e.g., "walked to the store" emphasizes that the event is completed and the agent who performed the action is at the goal state; Comrie, 1980; Vendler, 1957). The two aspects have different foci, which will have implications for what facets of the event are represented in the situation model. For example, events conveyed using the imperfective aspect are more likely to be interpreted as ongoing in a narrative than events conveyed using the perfective aspect (Madden & Zwaan, 2003; Magliano & Schliech, 2000; Morrow, 1990; Schramm, 1998) and ongoing events should be represented differently than completed events.

Second, aspect helps determine what information should be maintained and available in working memory over discourse segments in order to support situation model construction (Carreiras, Carriedo, Alonso, & Fernandez, 1997; Hopper, 1979; Magliano & Schliech, 2000; Morrow, 1985, 1986). Previous studies show that imperfective sentences are more likely to have information from the sentences foregrounded in working memory over the course of subsequent sentences than perfective sentences (Carreiras et al., 1997; Magliano & Schliech, 2000). This has implications for inference generation, such as the resolution of pronominal anaphors (Carreiras et al., 1997; Morrow, 1985). Third, there is a growing body of evidence that aspect affects the activation of different event knowledge associated with a verb predicate in a linguistic utterance (Elman, 2009; Ferretti et al., 2007; Ferretti & Katz, 2010; Hart & Albarracín, 2009). For example Ferretti et al. (2007) gave people sentence fragments describing events that were conveyed either with the imperfective (e.g., was skating) or with the perfective aspect (had skated) and had people complete the sentences. People were more likely to complete the imperfective fragments, relative to the perfective fragments, with a locative preposition ("in an arena"). In another experiment, people read sentences conveying actions using the imperfective and perfective aspects, each followed by a locative preposition. Event related potential (ERP) data revealed a larger N400 signal when locative prepositions followed a verb in the perfective aspect than the imperfective aspect, indicating that the different aspectual forms created different syntactic expectations.

Hart and Albarracín (2009) showed that the goal and intentions of agents were more available when readers processed sentences describing agents performing actions conveyed in the imperfective rather than perfective aspect. They argued that the imperfective aspect allows foregrounding of the goal because tension of a potential but unfulfilled goal exists (Hart and Albarracín (2009)). Experiment 3 of Hart and Albarracín (2009) is of central interest here because it demonstrates that aspect can affect higher order reasoning. People were given simple descriptions of a person committing a violent crime (e.g., shooting another person) using either the perfective or imperfective aspect. The violent act was more likely to be judged as premeditated following an imperfective compared to a perfective aspect condition. This shows that lower-level linguistic forms can influence higher order reasoning about an event. These studies suggest that the perfective aspect leads people to focus more on the entities or characters present and goal outcomes (e.g., Madden & Therriault, 2009) whereas the imperfective aspect leads people to be less aware of entities, but more aware of the action itself, in one way or another (Ferretti et al., 2007; Hart & Albarracín, 2009; Magliano & Schliech, 2000).

The aim of our study is to further explore the influence of aspect on complex cognition, and, in particular, reasoning about insight problems. Insight problems are often worded so that the successful solution is obscured in some way. Typically it is because generating the solution requires a person to think about and interpret the described state of affairs in a way that would be different from the way a person is likely to initially think about the described event. Thus, it is reasonable to expect that verb aspect affects the ability to solve insight problems to the extent that aspects affect the nature of situation models constructed.

1.1. Insight problems

Insight problems induce a form of language processing that unconventionally promotes a disharmony between meaning and context. By commonly relying on alternate or uncommon understandings in order for the proper answer to be derived, insight problems require a person to adjust and create a more appropriate situational model to solve them. Previous research has already explored a number of facets of insight problem solving, including verbalization during the task (Schooler, Ohlsson, & Brooks, 1993) and hints (Moss, Kotovsky, & Cagan, 2011). In attempting to solve insight problems, there seem to be two approaches. The first is a deductive reasoning and reportable method while the other is transient and "unreportable" (Gilhooly, Fioratou, & Henretty, 2010). This 'aha!' response when solving insight problems arises from a different understanding of the problem which would lead to the correct answer. Certain tactics help insight problem solving, such as hints given indirectly during comprehension, group work, and asking questions (Büttner, 2007; Mosset al., 2011). None of this, however, breaks down how situation models are constructed during this process.

It is reasonable to expect that the structure of the situation model influences the ease with which problems are solved (Johnson-Laird, 1983; Johnson-Laird, Byrne, & Schaeken, 1992). The aim of this study is to assess how cognition can be facilitated or hindered in the creation of a situation model as a function of the construction guidance provided by verb aspect. A central thesis of the current study is that aspect may affect the ability to solve insight problems to the extent that the different verb aspects emphasize knowledge that either leads to or hinders the arrival at an appropriate solution.

Consider the example problems shown in Table 1 that were used in this study. The actions were conveyed with either the perfective or imperfective aspect forms. Problem 1 describes an event in which a woman is navigating through a town and implicitly suggests that she may be violating traffic laws. However, she does not get a ticket. The correct inference to solve the problem involves how she is moving, and specifically that she is walking. We predicted that actions conveyed using the imperfective aspect

would support the correct solution more so than a perfective aspect because the imperfective places greater emphasis on the action. This would direct problem solvers to reason about those activities.

In comparison, Problems 4–6 all require solutions that run counter to gender stereotypes (e.g., Problem 4 can be solved by inferring that it was a women's basketball team). Given that the perfective aspect places less emphasis on the actions in the sentence, we predicted that the correct solution would be more supported by the perfective than the imperfective aspect. This is because the literature supports the idea that different verb aspects can change the focus on the gender of different characters (Ferretti, Rohde, Kehler, & Crutchley, 2009) in events. When the problem is conveyed in a perfective aspect, the situation model is not focused as strongly on the action, and so is available to explore other aspects of the described situation. This may include aspects that may not be represented in the structure of the event itself, as captured by the situation model, but to other types of information, such as that stored in semantic memory (e.g., gender roles). Each of the problems has cues that gender is a potential solution (e.g., no *man* scored a point). Once gender is considered, both genders should be available in working memory and the female gender should then be considered a potential solution to the problem. Conversely, in these problems, the imperfective aspect would misdirect readers' attention to the activities as they are represented in the situation model. As such, people would be less likely to consider other aspects of the problem, causing them to be more likely to adhere to gender stereotypes as the default.

Given this, it should be possible to explicitly manipulate people's focus during insight problems solving via aspect, and therefore the ease with which those problems are solved. This was explored in two experiments. In Experiment 1, people solved insight problems in which the solution depended on understanding how an action was done (Problems 1–3 in Table 1). As such, performance on the problems should be better when they are presented in the imperfective. In comparison, in Experiment 2, people had to solve insight problems in which the solution did not involve the action of the people in the problem, in this case their gender (Problems 4–6 in Table 1). As such, the prediction is that performance should be better when they are presented using the perfective rather than the imperfective aspect.

2. Experiment 1

This experiment explored whether problem solving would be improved when the imperfective verb aspect was used with problems that required an understanding of how an action was done within the time window of the event.

2.1. Method

2.1.1. Participants

A total of 585 adults (362 female) were recruited using the Mechanical Turk website and were reimbursed for their participation. 304 of these participants received the imperfective version of a problem, whereas 281 received the perfective version. Those that reported ranged in age from 18 to 82 years old (M = 34.7, SD = 12.4). All were native English speakers.

2.1.2. Materials

Experiment 1 used three experimental insight problems, each with two versions. An example is presented in Table 1. One version of a given problem used the imperfective verb aspect (was walking) and the other used the perfective aspect (walked). The problem required understanding the appropriate action to correctly solve it; that is, how the character's action was done. The assignment of participants to perfective or imperfective versions of the stories was a between-participants manipulation.

2.1.3. Procedure

The problems were presented on-line using the Mechanical Turk website, issued in a survey form. Participants read only one problem and were asked to provide an answer, or to indicate that they did not know. There was no limit set on response time. Only response accuracy was examined.

2.1.4. Problem scoring

Problems were determined to be solved correctly if the participants produced the CONCEPT of the character's activity. For example, for question 1, suggestions that the woman was riding a bicycle were acceptable, for question 2, answers stating that she was taking a bus were permitted, and for question 3, answers that she painted a picture of the flower were scored as correct. Although they deviate from the original answer, those answers were still plausible given the insight problem's wording.

2.2. Results and discussion

The accuracy data for problems in Experiment 1 are shown in Fig. 1. These data were submitted to a 2 way (Aspect: Perfective, Imperfective) ANOVA. As can be seen, people were more likely to correctly solve a problem when it was presented in the imperfective than the perfective aspect, $F(1,583) = 5.87$, $MSE = .248$, $p = .02$, $\eta^2 = .014$. This is consistent with the idea that imperfective aspect focuses on the action being done in the problem, which would be represented within the situation model for that event, making it more likely that the problem would be solved. Thus, the verb aspect guided understanding and influenced the ease with which a person arrived at a solution.

3. Experiment 2

The aim of Experiment 2 was to explore whether problem solving would be improved when the perfective verb aspect was used with problems that did not direct the focus of attention on the described actions captured in the situation model representation of the problem. Instead, these problems required that a person consider not the nature of the action conveyed within the temporal frame-

Table 1
Insight problems used in the experiments in both the imperfective and perfective aspect versions.

Experiment 1

1. An unemployed woman was not carrying/did not have her driver's license with her. She wasn't stopping/didn't stop at a railroad crossing, was ignoring/ignored a one-way traffic sign and was traveling/traveled three blocks in the wrong direction down the one-way street. All this was being observed/observed by a policeman, who was on duty, yet he was making/made no effort to arrest the woman. Why? (DeYoung, Flanders, & Peterson, 2008) SOLUTION: She was walking
2. A woman was traveling for the weekend. She was checking/checked her ticket, boarding/boarded, and placing/placed her luggage above her seat. The pilot did not show up, yet she and the other passengers were arriving/arrived at their destination without a delay. How? SOLUTION: She was traveling by train
3. A woman was inspecting/inspected a flower. She was hoping/hoped to bring it back to her lab without taking the flower out of its environment. However, even though the woman did not have a photographic memory, she was bringing/brought the flower back to the lab without damaging it. How? SOLUTION: She took a picture of the flower

Experiment 2

4. Our basketball team was winning/won 72–49, without one man scoring/and yet not one man scored as much as a single point. How is that possible? (DeYoung et al., 2008) SOLUTION: It was a women's team
5. A father and his son were in a car accident. They were being rushed/rushed to the hospital, as both of them were needing/needed immediate medical attention. The son required surgery. However, the surgeon was seeing/saw the boy's face before the operation and was saying/said, "This boy is my son." How? (Dow & Mayer, 2004) SOLUTION: The surgeon was the boy's mother
6. The jockey was riding/rode in a race. Their horse was taking/took the lead and it was clear that the jockey would win first place. Even though the horse was crossing/crossed the finish line without a man sitting on/a man on its back, they still won. How? SOLUTION: The jockey was a woman

work of the event, but the gender stereotypes conveyed in more generalized semantic memory.

3.1. Method

3.1.1. Participants

A total of 448 adults (238 female) were recruited using the Mechanical Turk website and were reimbursed for their participation. 206 of these participants received the imperfective version of a problem, whereas 242 received the perfective version. They ranged in age from 16 to 82 years old ($M = 33.8$, $SD = 11.9$). All participants were native English speakers.

3.1.2. Materials, procedure, and problem scoring

Experiment 2 used three experimental problems, again each with two versions. These problems are also presented in Table 1. One version of a given problem used the imperfective verb aspect (was walking) and the other used the perfective aspect (walked). As was the case with Experiment 1, assignment to the perfective and imperfective versions was a between participants manipulation, with each person seeing only one of these problems. The three problems did not require understanding how the character performed an action, but rather required an inference about other elements described in the problem, namely the gender of the people involved. The procedure for Experiment 2 was identical to that of Experiment 1, except that Problems 4–6 (Table 1) were used instead of Problems 1–3. Problems were scored as correctly solved if the participant produced that the characters in the problems were female.

3.2. Results and discussion

The accuracy data for experimental problems in Experiment 2, also shown in Fig. 1, were submitted to a 2 way (Aspect: Perfective, Imperfective) ANOVA. As can be seen, unlike Experiment 1, people were more likely to correctly solve a problem when it was presented in the perfective than the imperfective aspect, $F(1,446) = 8.34$, $MSE = .233$, $p = .0043$, $\eta^2 = .024$.[1] This is consistent with the idea that perfective aspect does not drive attention toward the action involved in a sentence as would be represented in the situation model. If it is not being misdirected, it is more likely that information in semantic memory might be consulted and used. Thus, once again, the verb aspect guides understanding and influences the ease with which a person arrives at a solution.

Additionally, we compared performance across the two experiments, using a 2 (Experiment) $\times$ 2 (Aspect: Perfective, Imperfective) ANOVA. In this analysis, there was a main effect of Experiment $F(1,719) = 12.62$, $MSE = .241$, $p < .001$, $\eta^2 = .017$, reflecting the fact that people found the problems in Experiment 1 easier to solve ($M = .52$) than those in Experiment 2 ($M = .40$). The main effect of aspect was not significant, $F < 1$, however, the interaction was, $F(1,719) = 3.37$, $MSE = .241$, $p < .001$, $\eta^2 = .019$. This supports the idea that the effects of the two experiments were meaningfully different.

4. General discussion

Overall, our results indicated that people are more likely to solve an insight problem when it is presented using a verb aspect that more easily allows access to the information that is more relevant for the appropriate solution. Specifically, one the one hand, problems were solved more often in the imperfective aspect when the solution depended on understanding how an action, conveyed in the situation model, was performed. On the other hand, in the context of problems where directing attention to the characters' actions was not relevant to the solution, problems were solved more often with the perfective aspect. In this case, an imperfective aspect likely hindered

[1] The completion rates showed the same pattern for all problem types. For the problems in Experiment 1, the imperfective/perfective solution rates were .76/.44, .59/.49, and .47/.45 for Problems 1 to 3, respectively, whereas for the problems in Experiment 2, the solution rates were .30/.53, .20/.37, and .48/.54 for Problems 4–6, respectively.

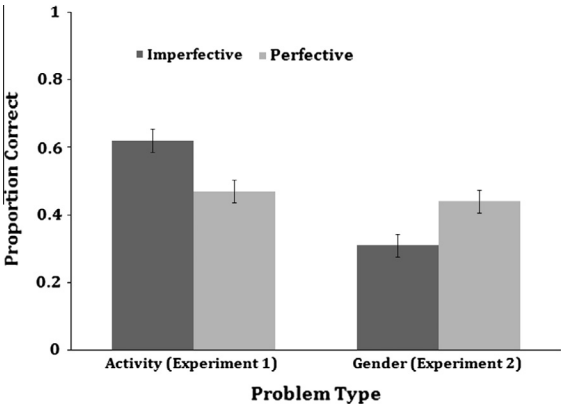

Fig. 1. Accuracy data for Experiments 1 and 2.

problem solving because it misdirects attentional resources to aspects of the problem not germane to the solution. Instead, the use of the perfective aspect in the context of these problems led to accessing information in semantic memory. In turn, that allowed readers to consider the gender of the characters as needed for the solution, because they were more likely to reflect upon other concepts of the problems rather than the actions. This is consistent with previous research showing that different verb aspects influenced the types of situation models that were constructed and what information was in the foreground of processing (Carreiras et al., 1997; Ferretti et al., 2007; Ferretti & Katz, 2010; Hart & Albarracín, 2009; Madden & Zwaan, 2003; Magliano & Schliech, 2000; Morrow, 1985, 1990).

The most important feature of the present study was not only that verb aspect influenced cognitive processes more closely associated with language comprehension itself, but that it had systematic and predictable influences on more complex cognitive processes that involved the output of such processes. In this case, reasoning about solutions of the insight problems. The only other study that we know of which showed that aspect has an impact on how people reason about problems presented in language is Hart and Albarracín (2011). They showed that an imperfective verb aspect can affect the accessibility of intentions of a perpetrator of violent crime, which in turn affects judgments regarding how premeditated the crime was. The results of the present study extended this finding and showed that problem-solving behavior can also be affected by different forms of aspect, depending on the nature of the problem. Thus, overall, the wording used in presenting information to people, including more subtle changes, such as changes in verb aspect, can meaningfully influence a person's ability to successfully engage in higher-level cognition.

One other point to note about the Hart and Albarracín (2011) study is that they showed that the goals of agents are more available when actions are described in an imperfective aspect than a perfective aspect. Goals are arguably a quality of a character, and these goals are more available when the actions are described in an imperfective than a perfective aspect. Moreover, in a study by Carreiras et al. (1997), people were more likely to retrieve a character's name from memory after reading an imperfective than a perfective verb. Again, the name is a quality of the character.

The results of these studies may seem to contradict those of Experiment 2, where the quality of character gender was more accessible with the perfective aspect, because Hart and Albarracín (2011) and Carreiras et al. (1997) both showed that qualities of characters are more accessible with an imperfective aspect. However, we believe that this contradiction is more apparent than real. In general, an imperfective verb in a narrative focuses attention more on the action being conveyed in the situation model, which is represented, in some sense, as ongoing and incomplete. As such, the protagonist performing the action is more likely to be more foregrounded with an imperfective verb than a perfective verb. In the case of the Hart and Albarracín study, the goals are characteristics of a person that explain their actions in that event. That explains why this kind of character information is highlighted in that case by the imperfective aspect. In comparison, in our Experiment 2, the gender of the protagonist is not directly relevant to the actions being performed, and so was unlikely to be initially captured in the situation model.

Furthermore, in the case of the Carreiras et al. (1997) study, the names of the characters were explicitly stated in the text, and so were part of the understanding of the unfolding event. These explicitly stated properties of that protagonist would be more likely to be part of the situation model under construction, and so would be more available with the imperfective aspect that focused attention on the actions and elements captured in the situation model. Moreover, the Carreiras et al. study directly probed participants for this explicitly stated name. In comparison, the current study asked for participants to generate a solution, which, in the case of our Experiment 2, often came from long-term semantic memory, rather than the current situation model. As such, in this context, using the imperfective verb aspect would misdirect the reader to the event-specific information and away from semantic memory, the source of the solution, whereas in the other studies it would have directed attention toward the source of the solution, the information in the developing situation model.

It is important to note that the effect sizes of the current study were small. This is in part due to the fact that only three problems were used in both experiments, which required a large sample. Moreover, the use of the an on-line data collection service has led to a relatively diverse sample in terms of linguistic proficiencies, cognitive abilities, experience with insight problems, and general background (Sprouse, 2011). We see the fact that there were reliable effects with a diverse sample not limited to college students as a virtue. Moreover, it is not surprising that the effects of aspect are subtle given the fact that solving insight problems requires deliberate and effortful problem solving. Therefore, it is even more remarkable that this sort of morphological difference affected higher level reasoning about the problems.

Overall, the results of the present study demonstrate that subtle aspects of language can affect the nature of

thought (Bloom, 1981; Boroditsky, 2001, 2011; Boroditsky & Gaby, 2010; Fausey & Boroditsky, 2010; Hunt & Agnoli, 1991). These linguistic systems constrain what knowledge is activated and available in working memory to support higher order reasoning and thinking (Fausey & Matlock, 2011; Hunt & Agnoli, 1991). Morphological systems associated with verb predicates may be particularly important because they activate the basic event schemas referenced in language (e.g., Elman, 2009; McRae, Ferretti, & Amyote, 1997). Verb aspect helps specify which elements of those schemas are directly relevant for the referenced situation model, even though it is part of a larger system of contextual (e.g., lexical, syntactic, semantic, pragmatic) factors that direct the activation of relevant knowledge in working memory.

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