Modeling the spatial compatibility effect in the context of a group task

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1 Introduction

Oftentimes certain tasks are easier to complete when working with others. Complex jobs naturally lend themselves to group work because they can be split into smaller, more specialized requirements that can be performed by different members of a group. While the concept of working in a group may be quite familiar, understanding the cognitive processes and representations at play in a group context is more subtle. While experiments have been conducted to answer these questions, few models have been designed to capture these phenomena. In the present study, we seek to construct a model of the cognitive processes underlying an individual's behavior in the context of a group task.

Having a model of cognitive processes within a group is important because it has the potential to explain effects found in experimental data at a lower, cognitive and even biological level. Our model is able to replicate the observed effects and shows that they can be created by a very simple architecture. It also has the potential to inspire other, more complex models of cognition or further experiments in group work. Since few other models of cognition in a group setting exist, our model has the obvious advantage of being new, despite possible shortcomings.

In this paper, we will review an experiment testing the effects of working in a group on cognition (2), then we will describe our model that aims to replicate the experiment (3.1), compare our results to the experimental results (3.2), and explain how and why our model works (3.3). Finally we will conclude with an evaluation of our model, what it might suggest and possible improvements (4).

2 Task Description

Two prevailing schools of thought seek to explain group work at a psychological level: social facilitation and ideomotor theories. Social facilitation research seeks to determine if working within the context of a group can affect behavior in a general sense. Ideomotor research looks at the more specific question of whether observation of a specific behavior can have a specific and predictable effect on one's own behavior. An example of this is moving different fingers up and down while watching someone else move their fingers up and down. Boyer, Scheutz and Bertenthal (2009) found that participants had little trouble doing this when there was a direct mapping between their actions and the stimulus action (i.e., like watching yourself wag your fingers in a mirror), but when that mapping was reversed, response times increased significantly. They also created a model of the experiment, which will be discussed in greater detail later.

To test these two competing theories, Sebanz, Knoblich and Prince (2009) designed a variant of the Simon spatial compatibility response time (RT) task observing the effects of a partner (Simon, 1990). A typical Simon task presents a subject with one of two stimuli (e.g., a red or green dot on a screen) and the subject must respond with the correct button input as quickly as possible. Additionally, an irrelevant spatial stimulus is presented (e.g., a finger pointing left, right or up), which has no relation to the correct button input but may have an effect on performance. This effect is known as the spatial compatibility effect, which is when people find it easier to respond when the spatial stimulus corresponds to the target button press (e.g., the finger is pointing left and the correct input is the left button press).

Although many different conditions were tested in their experiment, the most interesting experiment they performed was comparing the effects of spatial compatibility in a Simon go-nogo task. In the go-nogo variant, participants are only responsible for responding to one stimulus. For instance, a participant might be responsible for pressing their button as soon as they see the red stimulus. Two variants of this specific task were tested: individual and joint. In the individual condition, a participant sat alone at a computer and pressed their button as soon as they saw their stimulus. In the joint condition, two participants shared a computer and each were responsible for responding to one of the stimuli. Additionally, researchers manipulated the irrelevant spatial stimulus to either be compatible (finger always points to who should press their button), neutral (finger always points in a neutral direction) or incompatible (finger always points away from the person who should press their button). For the sake of simplicity, we chose not to incorporate the neutral condition into our model.

This experiment, although relatively simple, could be modeled a few different ways. We chose to use a connectionist model because it requires little knowledge about input stimuli and allows for a straightforward mapping of outputs. One inspiration for our model was the model constructed by Boyer et al. (2009), which modeled the effects of spatial compatibility in an ideomotor task. They used an interactive activation and competition (IAC) model and mapped the number of response cycles taken to reach threshold activation of the output nodes to participant response time. Since the phenomenon being modeled by Boyer et al. (2009) was similar to what we are studying, we chose to use the same modeling paradigm and output mapping.

An important aspect of our design is that we chose to only model the cognitive processes of a single participant. One could potentially design a model that models both participants (in the joint condition), but doing so would have significantly complicated our model. Instead of modeling both participants, we represented the presence of a partner as an input stimulus to the participant being modeled. This input was represented as a binary value, i.e., there is a partner (joint condition) or there isn't a partner (individual condition). A full description of our model is given below.

3 The Model

3.1 Description

Our model was built using PDPtool developed by McClelland and Rumelhart using an IAC network type (McClelland & Rumelhart, 1989). In our model, three pools of input nodes correspond to the three categories of stimuli presented to the participant: color (my color or the other color), the irrelevant spatial stimulus (compatible or incompatible) and partner (joint vs. individual). The spatial stimulus and partner pools were projected to a hidden node representing spatial compatibility (or incompatibility). The partner pool projects to this node because Sebanz et al. (2009) found that the presence of a partner seems to influence the spatial compatibility effect. This spatial compatibility pool and the input color pool both project to the hidden node known as ”me.” The ”me” node is intended to represent the degree to which the participant feels the stimuli is for *them*. Finally, the ”me” node projects to the ”press button” node, which is the final output of the model. When activation at this node rises to at least 0.90 (0-1), the node is assumed to fire and cause the participant to press their button. See Figure 1 for a visual representation of the model.

Minimum activation was 0.0, maximum activation was 1.0, resting activation was 0.0 and decay rate was set at 0.001. The standard activation function was used for all nodes. Input activation was either 1.0 or 0.0 and input patterns corresponded to the conditions tested in the original experiment. All connections were set to a weight of 1.0 or -1.0, except for the connections between color and ”me.” These were set to 3.0 and -3.0 so as to lessen the effect of spatial compatibility on the output.

Since error rates in the original experiment were approximately 1%, only trials that would result in a button press were measured. However, we did test the model with the ”other color” input, and output activation never reached the threshold. Noise was also excluded from the model because we were only modeling mean response time and it would have made it more difficult to adjust the parameters appropriately.

3.2 Experiments and Results

Like the findings from the original experiment, the generated data from the model show the same interaction effect between spatial compatibility and presence of a partner (see Figures 2 and 3). To convert update cycles to response time (msec), multiply the number of update cycles by 10.5. The most prominent difference between the data is that the model data show a stronger main effect for spatial compatibility and a stronger interaction between conditions. And although it may appear that the experimental data show a significant difference between the joint and individual conditions, no significant difference was found (which is also true of the model data). Overall, the model data demonstrate the same effect patterns as the experimental data.

3.3 Analysis

The current model is best explained through an example, so we will walk through what happens the presented stimulus is your color (i.e., you should press your button), the spatial stimulus is compatible (it's pointing towards you) and you have a partner. Since it's your color, the-my color input node is activated with 1.0. And since it's compatible, the compatible input node is also activated with 1.0. And since you have a partner, the partner node receives 1.0 (0.0 represents

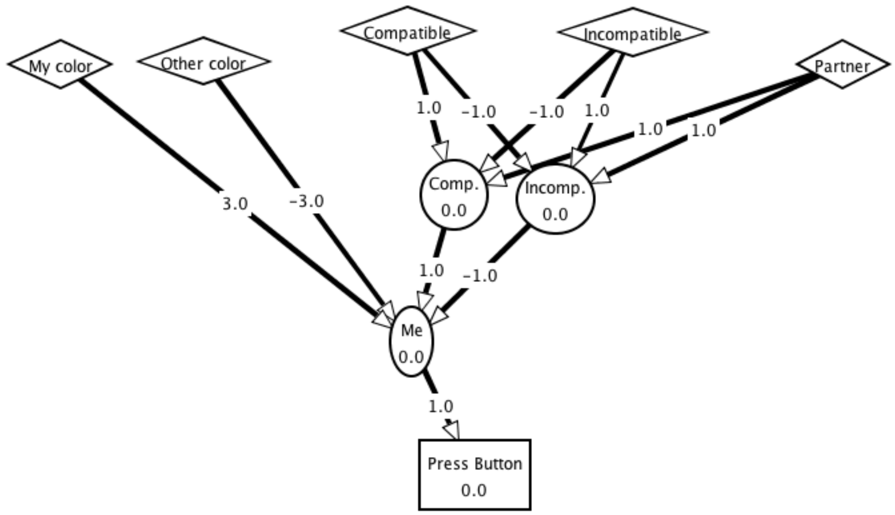

Figure 1: A visual representation of the designed model. My color and Other color make up the color pool, compatible and incompatible make up the spatial stimulus pool and comp. and incomp. make up the spatial compatibility pool. The 0.0 below some nodes refers to its current activation, but no activation is currently being applied.

the individual condition). Since it's your color, the "me" node is strongly activated by the my-color node (wt. 3.0). And since the stimulus is spatially compatible, the spatial compatibility node is activated. If the stimulus was incompatible then the spatial incompatibility node would be activated. Also, since there is a partner, the activation of spatial compatibility is intensified. This is to reflect the experimental data showing that a partner magnifies the spatial compatibility effect. Conversely, if there's a partner but the stimulus is incompatible, then the spatial incompatibility node is activated more strongly, so as to reflect the data. In other words, if there's a partner and the stimulus is incompatible, then you'll take even longer to respond. Next, the spatial-comp activates the "me" node. This is because, when you have a partner, seeing a spatially compatible stimulus makes the notion of the stimulus being "for you" stronger (as can be inferred from the data). Finally, the "me" node activates the press-button output node, which is said to exceed its threshold activation once its activation is at least 0.90.

The greatest advantages of the model is its simplicity and ability to fit the data. We do not believe the observed effects could be demonstrated with a simpler model. Also, like all connectionist networks, the model has some biological plausibility because each node operates like a neuron or a collection of neurons. The model can also be used in interesting ways, like by altering the input activation of the partner node to simulate different levels of "partnership" (i.e., no partner, person present, partner w/ no feedback, or partner w/ feedback). The major disadvantage of the model is that it doesn't shed much light on the the cognitive processes responsible for the demonstrated spatial compatibility bias. In reality, there are probably some intermediary nodes between "partner" and "spatial-comp", but since these underlying cognitive processes are poorly understood, we thought it would be better to omit such nodes.

One way the model could be improved is the model data mapped more precisely to the experimental data. This might be achieved by using less activation and observing the model over more cycles (>100). It would also be interesting to construct a model of the two-choice task using the

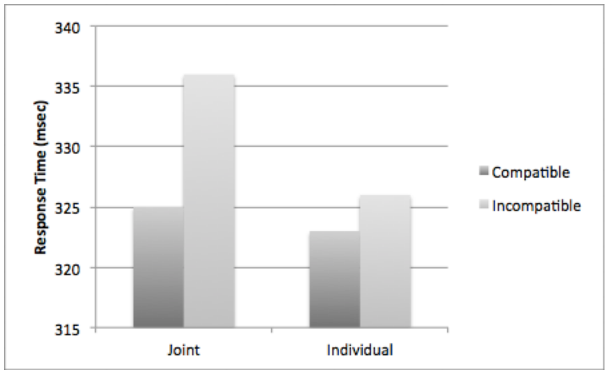

Figure 2: Partial results from experiment by Sebanz et al. (2003) showing mean response times for variants of the go-nogo task.

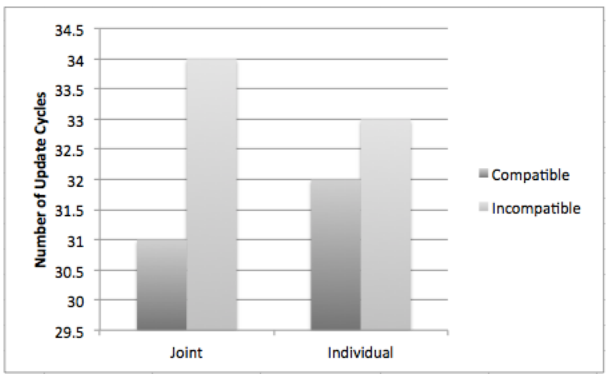

Figure 3: Results from IAC model showing the number of update cycles taken for the output activation to exceed 0.90.

same weights to see if the spatial compatibility effect would still be demonstrated.

4 Conclusion

The model was designed to recreate the effects demonstrated by Sebanz et al. (2009). Specifically, we wanted to show that the spatial compatibility effect could be influenced by the presence of a partner. In this regard, the model was successful, although the demonstrated interaction was stronger than predicted by the experimental data. Since the model architecture was designed for a very specific experimental design, it cannot easily be extended to model other tasks. However, it could be used to simulate the second half of Sebanz et al. (2009) experiment, which manipulated the level of interaction between task partners. This could be simulated by using a non-binary input (i.e., something between 0.0 and 1.0) for the activation of the partner node. Possible improvements to the model include manipulating the parameters to fit the data more closely and scaling down activation to slow down the model, thus using more update cycles and yielding higher precision.

While our model was successful in replicating the observed findings from experimental research, it unfortunately did little to explain the underlying mechanisms of group tasks. More experiments (and models) must be completed to probe these question further.

5 References

References

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