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The Impact of Training on Naming and Producing Actions to Novel Objects

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

Visual object similarity, action similarity and semantic information are believed to influence both object naming and action production. The Naming and Action Model (NAM) developed by Yoon, Heinke, and Humphreys (2002) suggests that naming objects requires access to semantics, but that there are two routes to action production; an indirect route via semantics, and a direct route that bypasses semantics. For example, when presented with a known object like a hammer, one may retrieve action information from the representational knowledge of its function or directly from its visual characteristics. Past research suggests that producing actions with known objects relies mostly on using the direct route and producing actions with novel objects relies mostly on using the indirect route via semantics. However, this has not been clearly shown. Therefore, the current study examines the role of semantics on object naming and producing actions when training on novel object-action associations. Participants were asked to learn novel object-action associations that were labeled with either the names of semantically similar items or semantically dissimilar items. After an initial learning session, participants named the objects, produced novel actions with the objects and produced novel actions with a cylinder in response to the previously learned labels. Participants then practiced the actions with the objects over three sessions. During the final session, participants were given a reminder of the object-action associations and then they were tested on them again. Results showed that before and after practice, participants made more naming errors and action errors with the cylinder for objects associated with semantically similar labels than objects associated with semantically dissimilar labels. This suggests that when naming objects and producing actions with the cylinder before and after practice, participants were likely relying on the semantic route. However, when participants produced actions with the objects, the pattern of results was

different. Before practice, participants made more action errors with objects associated with semantically similar labels than objects associated with semantically dissimilar labels. After practice, participants made equivalent numbers of action errors for objects associated with semantically similar and dissimilar labels. This suggests that participants were likely using the semantic route before practice and the direct route after practice.

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Dedication

I would like to dedicate my work to my wonderful family who has supported me in every possible way.

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1.0 Introduction

Recognizing objects and using them is something that we, as humans, perform every single day. Even so, this very important ability is most of the time taken for granted. For example, when looking at a pencil, we automatically recognize that it is a pencil and it is used for writing. However, some people might lose this important ability. For instance, some neurological patients have difficulty recognizing or naming objects, while others have difficulty using objects. One type of error that these patients make is a substitution error. This error occurs when a target object or action is substituted with another object or action (Giovannetti, Libon, Buxbaum, & Schwartz, 2007). An example of an object substitution error is using a spon to spread butter instead of using a knife. An example of an action substitution error is spooning rather than pouring cream into coffee. These substitution errors are not made exclusively by neurological patients. It seems that every once in a while, healthy people make substitution errors as well. Since recognizing objects and using them is something that we do everyday, it is very important to examine the factors that influence errors on object naming and producing actions with objects. Past research has suggested that visually similar objects take more time to be identified than visually dissimilar objects (Humphreys & Forde, 2001). Also, it has been shown that people have difficulty recognizing that two similar gestures represent the same gesture (Ska & Croisile, 1998). In essence, visual object similarity and action similarity influence both object naming and producing actions with objects. Another factor that seems to influence object recognition and action production is semantics. The semantic system is defined as the store of meaningful information for words and objects such as category, functions, and other associated relationships (Rothi & Heilman, 1997). Past research has shown that when naming objects, people confuse semantically similar objects more often than semantically dissimilar objects (Vitkovitch, Humphreys, & Lloyd-Jones, 1993). However, the role of semantics on action production remains unclear. Therefore, the current study examines the role of semantics on errors of naming and producing actions with objects when training on object-action associations.

Research on brain injured patients suggests that there is a dissociation between object recognition and action identification or production. First, several studies have shown patients who had difficulty in naming objects, but demonstrated relatively normal performance using them. For example, Schwartz, Barrett, Crucian, and Heilman (1998) described a patient, W.A., who had damage in the occipital-temporal regions. When they visually presented the tools to him, he could not name them. However, when they tactilely presented the tools to him when his eyes were closed and when they gave him a verbal description of the tools, he could name most of them. In addition, he performed very well when he gestured to command and when he imitated gestures. Overall, W.A. was able to recognize gestures, but he was unable to recognize visually presented objects. Similarly, Riddoch, Humphreys, Heslop, and Castermans (2002) tested patient M.C., who had Alzheimer's disease, on his ability to name and use real objects. When they visually presented the objects to him, he named only 55.9 % of the presented objects. On the other hand, he performed well when he produced the actions associated with the objects; he produced correct actions 84.8 % of the time. These results suggest that patients can show correct use of objects for objects they can not name correctly.

Second, several studies have shown patients who had difficulty in using objects, but demonstrated relatively normal performance in naming them. For instance, Hodges, Spatt, and Patterson (1999) asked patient F.L., who had corticobasal degeneration, to name and use real objects. When they presented her with twenty objects, she correctly named most of them. However, she performed correct actions with only twelve objects. Hence, the double dissociation between object naming and producing actions with objects suggests that object recognition and action production are two independent processes.

The first section of the introduction will further explore the influence of semantics in recognizing or naming objects. Similarly, the second section will explore the influence of semantics in producing actions with objects. In the third section, a general model of naming and gesturing in response to objects is presented. The model will illustrate how access to semantics is required when naming objects, whereas access to semantics is not required when producing actions in response to objects. The fourth section will raise issues regarding the use of common objects to investigate object naming and producing actions with objects. This section will explain how the use of common objects results in problems in interpreting findings which can be avoided by using novel objects. The fifth section will introduce the current study, which aims to demonstrate the role of semantics in naming and producing actions with novel objects.

1.1 Recognizing or Naming Objects

1.1.1 Patients

Patients with optic aphasia have difficulty naming objects. Beauvois and Saillant (1985) described optic aphasic patients as being impaired in naming visually presented objects but not in using objects. Hillis and Caramazza (1995) tested an optic aphasic patient, D.H.Y. on her picture naming abilities by asking her to name two hundred and sixty line drawings of objects. D.H.Y. could not name 90 % of the drawings, and 75 % of her errors were semantic. For example, when D.H.Y. was presented with a line drawing of an axe, she would call it a wrench. This was a semantic error since both the axe and the wrench belong to the category of tools. It is worth noting that D.H.Y was able to name objects when given a definition and when she was able to interact with the object tactilely. So, D.H.Y.’s naming difficulty was only evident when she was presented with the drawings visually. Then, the researchers wanted to determine at what level of the semantic system D.H.Y. was impaired. First, they tested her ability to access the semantic system by asking her to sort 26 pictures into animal or plant categories. Also, they asked her to identify which two of three presented pictures were related. For instance, she had to choose which two of pear, light bulb, and light switch were related. D.H.Y. was 100 % correct on both of these tasks, and therefore showed good access to the semantic system. Next, the researchers tested her ability to process semantic information by making the previous tests more specific. For example, they asked her to sort pictures into dogs and cats categories. Also, they presented her with two semantically related pictures, and asked her to identify which one was related to a third picture. For instance, they asked her to identify which one of a light bulb and a traffic light is associated with a light switch. D.H.Y.'s performance on both of these tasks dropped dramatically to 57.9 % compared to when she was given the tasks the first time. Hillis and Caramazza concluded that D.H.Y. was impaired in accessing complete semantic information from vision since she showed a drop in performance when she was required to access specific information to distinguish between semantically related pictures compared to when she was required to access general information.

Similar to patients with optic aphasia, patients with semantic dementia have difficulty naming objects. Hodges, Bozeat, Lambon Ralph, Patterson, and Spatt (2000) tested nine patients with semantic dementia on their naming abilities by asking them to name colour photographs depicting twenty common objects. Results showed that all nine patients had impaired naming ability. More specifically, four of the nine patients could not name any photograph. Also, Hodges et al. (2000) tested the patients on their semantic abilities. One of the tests was matching objects for shared purpose. In this test, they showed the patients four photographs of common objects, one of which was a target photograph. Then, they asked the patients to choose which of the three objects could be used instead of the target object. For example, they showed patients a photograph of scissors and they asked them to choose between photographs of knife, sellotape and pliers. They found that eight of the nine patients performed below the normal range. More specifically, five of the patients performed at chance. Hence, the patients appeared to have impaired semantic knowledge. Overall, the pattern of naming errors from patients with optic aphasia and semantic dementia suggests that semantics play an integral role in naming visually presented objects. However, in order to have a complete picture of the role of semantics in naming objects, evidence from healthy adults needs to be discussed.

1.1.2 Healthy Adults

Similar to patients who have already a difficulty in naming visually presented objects, healthy people can be induced to confuse object names by the use of the deadline method. Rumiati and Humphreys (1998) asked healthy participants to name line drawings of objects under a deadline of 450 ms. Essentially, in a deadline condition, participants are required to respond as fast as possible while trying to be as accurate as possible. The deadline procedure is used to induce participants to make errors by encouraging them to produce names and/or actions quickly. It is worth noting that the deadline that Rumiati and Humphreys used was not a strict deadline; names that were said after 450 ms were included in the analysis. Results showed that most of the naming errors that participants made were semantic in nature. The authors categorized an error as semantic when a participant confused an object with another one that is from the same functional category. For example, a participant might have confused a hammer with a saw; both objects are tools. Rumiati and Humphreys suggested that semantic errors prevailed in naming because access to semantics is required when naming objects.

Humphreys, Price, and Riddoch (1999) suggested that there are three main stages during object naming. First, when an object is seen, early visual processes encode the shape and other details of the object. This perceptual information then activates a structural description system. Essentially, structural description refers to visual representations of any object that is composed of parts and spatial relations among these parts (Farah, 1991). Second, the semantic system is accessed. The semantic system contains functional and associative knowledge about the object. Third, a phonological output is produced. Humphreys et al. (1999) explained that impairments at different stages of the naming process result in different types of errors. First, patients who are impaired with accessing the stored structural description system are impaired on object decision tasks, where discrimination between real objects and non-objects is required (Hillis & Caramazza, 1995). Usually, these patients are not impaired on high-level perceptual tasks, such as matching objects shown in unusual views (Gainotti & Silveri, 1996). This shows that these patients are impaired at accessing visual memory about the objects. Second, patients who are impaired with accessing the semantic system are not impaired on object decision tasks, but they are impaired on matching tasks, where participants must match one object to one of two other objects, one of which is semantically related to the first. For example, they would have to match a hammer to either a nail or screw. Usually these patients are not impaired on semantics tests from audition (Riddoch & Humphreys, 1987). This shows that these patients are impaired at accessing semantic knowledge from vision. Third, patients who are impaired with accessing the phonological output are not impaired on object decision and matching tasks, but are unable to name the object. Overall, evidence from both patients and healthy adults suggests that semantics plays an important role in naming objects; but what about the role of semantics in producing actions with objects?

1.2 Producing Actions Associated with Objects

1.2.1 Patients

Similar to previous research that showed patients with optic aphasia and semantic dementia have difficulty in recognizing objects, research has shown that patients with apraxia have difficulty producing actions in response to objects. Apraxia is defined as impairment in object use which cannot be explained on the basis of deficits in object recognition, comprehension, and basic motor control (Wheaton & Hallett, 2007). Buxbaum, Schwartz, Coslett, and Carew (1995) tested apraxic patient M.M., who had impairments in gesture pantomime and imitation. An assessment of gesture production showed that M.M.'s performance was normal when he used his right hand. However, when the researchers named an object to him or showed him the object itself, he was unable to demonstrate with his left hand how to use it. When the researchers allowed M.M. to hold the object and interact with it, his performance with his left hand improved. The authors then tested M.M.'s gesture imitation abilities and found that his performance improved when they allowed him to hold the object. Buxbaum et al. (1995) speculated that M.M. might have ideational apraxia, which is characterized by impairments in performing a complex sequence of actions with multiple objects. Therefore, they tested him on naturalistic actions with multiple objects. For example, they asked him to make a single slice of toast with butter and jelly, which required him to use both of his hands at the same time. Results showed that he produced errors on multiple objects tasks with the left hand. For example, when they asked him to prepare and pack a lunch, he wiped up spilled mustard with tin foil instead of a paper towel using his left hand. However unlike in simple gesture tasks with no sequence of actions required, M.M.'s performance with his right hand was impaired. For example, when M.M. grasped a knife using his right hand, he did so as if it was an ice-pick and used it with a stabbing motion. More importantly, the pattern of errors for the left and the right hand were different. In essence, errors with the left hand involved substituting a conceptually related, but incorrect object (using tin foil instead of paper towel). On the other hand, errors with the right hand involved incorrect spatial orientation (wrongly grasping knife as an ice-pick). Then, the researchers asked M.M. to perform the actions using only one hand at a time, and found that performance with the left hand improved. Therefore, these results suggest that the errors for the left hand, at least, reflect the effects of impaired access to semantic memory since they involved substituting a conceptually related object. Hence, it seems that semantics play a role in producing actions with objects.

To determine if semantic memory is important for the appropriate use of objects in routine skilled actions, Buxbaum, Schwartz, and Carew (1997) tested two patients. The first patient; D.M., had semantic dementia and the second patient; H.B., had Alzheimer's disease. Buxbaum et al. (1997) assessed both patients on the integrity of their semantic and action production abilities. An example of a semantic test was to point to an object; such as a light bulb, in order to pair it with one of five objects that is functionally associated with a target object; such as a lamp. Some examples of action tests were to use a pencil, prepare a slice of toast, and wrap a gift. Results showed that D.M. had impaired semantic knowledge. For example, he could not point to the correct object out of an array of five to pair it with a target object. However, he had no impairments in producing actions with objects. On the other hand, H.B. had no semantic impairments. However, he had impairments in producing actions with objects. For example, when the researchers asked H.B. to prepare a slice of toast, he sometimes omitted steps; such as not adding jelly on toast, or he sometimes added steps; such as wrapping toast in paper towel. On another instance when the researchers asked H.B. to wrap a gift, he made a sequence error; such as closing the gift box before putting the gift inside the box or he made a semantic substitution error; such as wrapping the tissue paper around the box instead of around the gift. Buxbaum et al. (1997) argued that D.M.'s performance suggests that access to semantic memory for objects is not necessary for action production. On the other hand, they argued that H.B.'s performance suggests that access to semantic memory for objects is not sufficient for action production. Therefore, it seems that semantics might not be needed to produce an action with an object.

Similarly, the performance of visual apraxic patients also shows that semantics might not be necessary for action production. Riddoch, Humphreys, and Price (1989) described visual apraxic patients as being impaired in gesturing to visually presented objects along with a relatively spared ability to name objects from vision. The researchers tested C.D., a visual apraxic patient, on his ability to access the semantic system. For example, they asked him to demonstrate which two of three pictures can be used to perform the same function. C.D.'s performance was normal indicating good visual access to semantics. Then, they tested C.D. on his gesturing and naming abilities. They presented C.D. with an object, such as a pen, and asked him to use the object while holding it and then they asked him to name it. Results showed that C.D. was unable to produce correct gestures, but he was able to name the objects. Also, Riddoch et al. (1989) asked C.D. to use the items that were presented to him from before after providing him with their names. They found that C.D. was able to produce correct gestures. Therefore, C.D. was able to gesture to command, but not to visually presented objects. The researchers suggested that C.D.'s impairment is due to damage to a possible direct route that exists between vision and the action system. Overall, the pattern of action errors of patients with apraxia shows that access to semantics is not sufficient and at the same time is not necessary for action production. However, in order to have a better picture on the role of semantics in producing actions, evidence from healthy adults needs to be discussed.

1.2.2 Healthy Adults

Similar to patients who have already a difficulty in producing actions in response to objects, healthy people can be induced to confuse actions associated with objects by the use of the deadline method. Rumiati and Humphreys (1998) asked healthy participants to make gestures in response to line drawings of objects under a deadline of 450 ms. Results showed that most of the action production errors that participants made were visual in nature. The authors categorized an error as visual when a participant confused an object with another one that is similar in shape. For example, a participant might have produced the action of a razor when presented with a hammer; both objects have similar structural representations. Rumiati and Humphreys suggested that visual errors arise in gesturing because action knowledge can be activated directly from the visual representations of objects and that the deadline prevents full activation of action responses. Therefore, the produced actions are based on incomplete activation of visual information shared by more than one object. Nonetheless, some of the action production errors that participants made were semantic in nature as well. The authors categorized an error as semantic when a participant confused an object with another one that is from the same functional category. For example, the participant might have produced the action of a saw when presented with a hammer; two tools. They suggested that these semantic errors arise because of a possible involvement of semantics in producing actions with objects.

It seems that actions can be produced with or without access to semantics. It might be that in some circumstances, access to semantics is required to produce an action, while in other circumstances, it is not. Phillips, Humphreys, Noppeney and Price (2002) examined the neural substrates of action retrieval from objects using positron emission topography (PET). In one experiment, they showed different participants words (names of objects) or line drawings of objects and non-objects. They asked the participants to press a key indicating whether the object would require a pouring or a twisting motion. An example of an object that could be used in a pouring action was a teapot. An example of an object that could be used in a twisting action was a key. In a second experiment, they showed different participants words (names of objects) or photographs of objects and non-objects (scrambled photographs) that either could be used in a pouring or twisting action. They asked participants to gesture a pouring or a twisting action using a manipulandum upon seeing each photograph. In both experiments, activation was seen in left inferior frontal, left posterior middle temporal and left anterior temporal cortices. All these areas, with the exception of the left posterior middle temporal cortex, are components of the semantic system (Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996). The left posterior middle temporal cortex is an action specific area. Importantly, in comparison to semantic activation in response to words, there was decreased activation in the left anterior fusiform area; a semantic retrieval region, for photographs of real objects, and in the left anterior temporal cortex for photographs of non-objects in the first experiment and for photographs of real objects in the second experiment. In addition, actions to non-objects resulted in activation in an occipital-temporal region; not a semantically related region. These results show that different semantics areas are activated depending on the characteristics of the stimulus. In essence, words and photographs of real objects resulted in more activations of semantics areas, whereas, photographs of non-objects resulted in less activations of semantic areas. So far, the role of semantics in naming objects and producing actions with objects have been discussed separately, therefore, the following section will put the evidence from the previous studies together and discuss the influence of semantics in both naming objects and producing actions with objects.

1.3 Naming and Action Model

Yoon, Heinke, and Humphreys (2002) suggested a model for naming objects and producing their associated actions based on visual and semantic routes. The Naming and Action Model (NAM) explains how objects have access to naming via semantics and how objects have access to actions using an indirect route via semantics or using a direct visual route (Figure 1). According to the NAM, the structural description system is activated upon the visual presentation of an object. Within the structural description system, input units that encode the visual features of each segment of the object are activated, which then activates a radial basis function (RBF) network that highlights the structural similarity between objects. The output of the structural description system then activates the semantic system (Figure 1, route (a)) According to Yoon et al. (2002), the semantic system contains super-ordinate knowledge (for example, tools) as well as item-specific knowledge (for example, hammer). Then, the semantic system activates a phonological name output (Figure 1, route (b)) and an action output (Figure 1, route (d)). In addition, the output of the structural description system directly activates the action output without passing through the semantic system (Figure 1, route (c)). Therefore, object similarity, object names, and action features associated with objects all form a semantic network where there is an interaction between object naming, action production, and action identification.

According to the NAM (Yoon et al., 2002), naming substitution errors can arise from the confusion between two visually similar objects and/or two semantically similar objects. Similarly, action substitution errors can arise from the confusion between two visually similar actions and/or the confusion between two semantically similar actions. In previous research, it was not

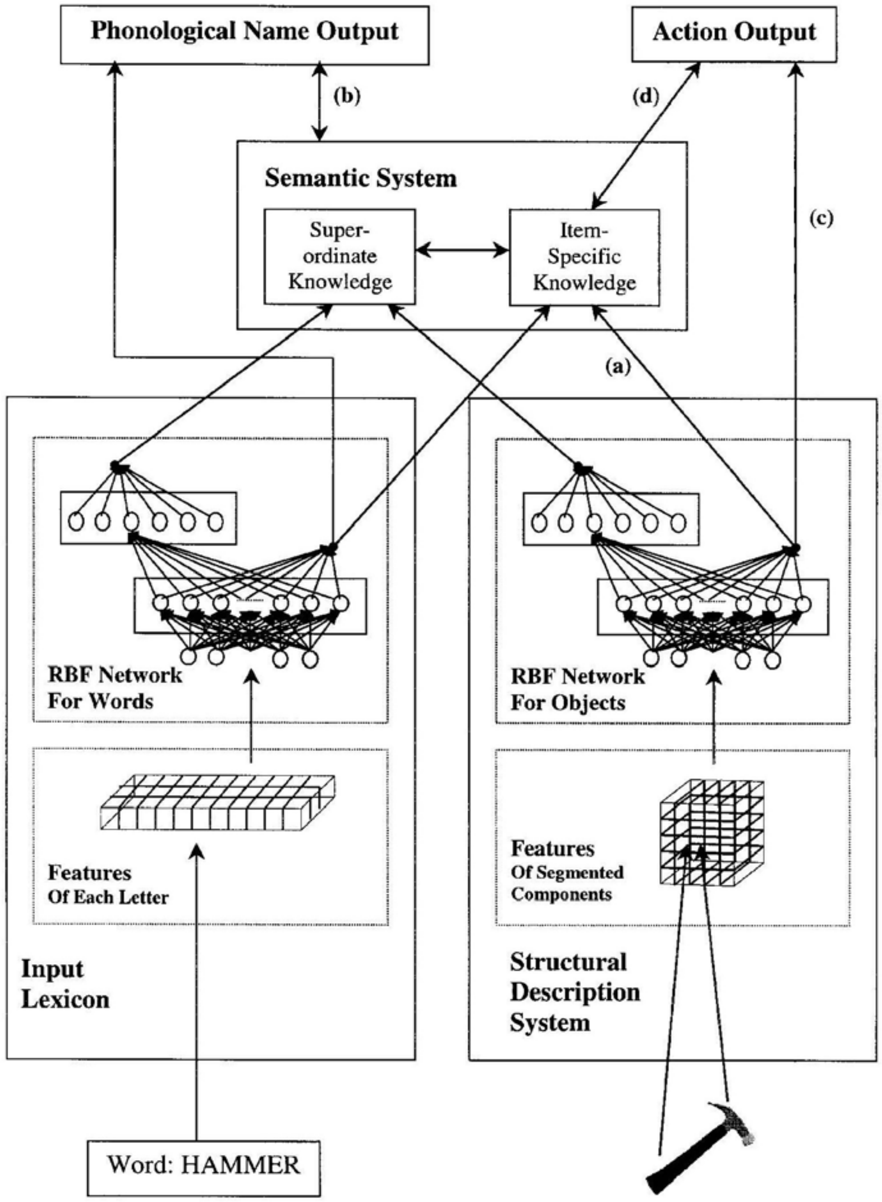

Figure 1. Naming and Action Model. Reprinted from "Modelling Direct Perceptual Constraints on Action Selection: The Naming and Action Model (NAM)," by E. Y. Yoon, D. Heinke, and G. W. Humphreys, 2002, *Visual Cognition*, *9 (4/5)*, p. 624 (2002). Copyright 2002 by the Psychology Press Ltd. Reprinted with permission.

possible to determine if errors were based on visual or semantic similarity since common objects were used. In order to observe the influence of semantic similarity in naming objects and producing actions, visual similarity should be held constant. The use of novel objects achieves this purpose.

1.4 Novel Objects

To try to study problems in object identification and usage, participants have been tested using common objects for which there already were long-established connections to semantics and actions. This situation can create confounding factors. For example, when a person mistakenly identifies a saw as a knife, this confusion might be due to the fact that the knife and the saw are visually similar. However, the confusion between the knife and the saw might also arise because their actions are similar; both the knife and the saw are used in similar ways. In addition, this confusion could arise because of similar affordances; both the knife and the saw afford cutting. Humphreys (2001) described affordances as particular categories of action that may be activated directly by the visual representations of an object. Tucker and Ellis (1998) showed that seeing objects automatically primes components of actions they afford, even if a person has no intention of using the object. More specifically, they examined the relation between an object's orientation and the hand most suited to perform a reach and grasp movement. They presented photographs of household objects to participants in two horizontal orientations; one orientation was compatible with a right hand grasp and the other orientation was compatible with a left hand grasp. Also, they presented objects to participants in two vertical orientations; one orientation was upright and the other orientation was inverted. The researchers asked the participants to decide as fast as possible whether each object was upright or inverted by making key presses. Results revealed that participants were faster and more accurate using their right hand when the object's horizontal orientation was compatible with a right hand grasp. Similarly, participants were faster and more accurate using their left hand when the object's horizontal orientation was compatible with a left hand grasp. The authors concluded that there are existing action representations when people intend to perform an action, and when they perform the actual action, they select these representations.

Because real objects have affordances and so are linked to particular actions, and in order to separately look at the impact of visual object similarity, action similarity and semantics on object naming and action production, one needs a set of objects and actions that are free of previous associations. In this way, the researcher can control visual and action similarity, and establish semantic representations for participants. Such objects and actions have been used by Desmarais, Pensa, Dixon and Roy (2007). Essentially, they used eight novel objects and asked participants to associate novel names and actions to them. Their results suggested that people often confuse actions that are visually similar, as well as actions that are associated with visually similar objects. The authors demonstrated this phenomenon by asking healthy participants to learn to identify and use eight novel objects that were each associated with one of eight novel actions. All participants received blocks of learning and testing trials. During learning trials, they showed participants each object mounted on a manipulandum, a non-word label or "name" for that object, and an action that was performed with that object. For example, when a cucumber shaped object was shown, the label 'yoot' was shown, and the object was shown to be used in a particular way (e.g., pulled). During testing trials, each object was mounted on the manipulandum, and the researcher asked participants to name each object using its non-word label and then to either perform the action associated with it or to identify its action by selecting the correct action from a number of sequentially presented digital movie clips. It is important to note that the authors used one crucial manipulation in the learning trials. For one group of participants, action similarity and visual object similarity were aligned: similar actions were associated with similar objects and dissimilar actions were associated with dissimilar objects. For the other group of participants, action similarity and visual object similarity were misaligned: similar actions were associated with dissimilar objects and dissimilar actions were associated with similar objects. This allowed the authors to examine the impact of visual object similarity on action identification and action production. When participants produced an error, the authors noted which two actions had been confused. Their results suggested that action similarity played a role in action production; similar actions were confused more often than dissimilar actions. More interestingly visual object similarity also affected action errors where participants confused actions more often when they were associated with visually similar objects than when the same actions were associated with visually dissimilar objects. This study conclusively demonstrated that the visual characteristics of the objects influenced action identification and action production.

Similarly, Desmarais, Dixon, and Roy (2007) used the same paradigm described above for naming objects. Their results showed that participants confused objects that were visually similar more often than objects that were visually dissimilar. Furthermore, participants confused similar objects more often when they were paired with similar actions than when they were paired with dissimilar actions. This study demonstrated that the similarity of the actions associated with objects influenced the pattern of errors observed when naming these objects. Overall, using novel objects enabled the decoupling of visual object and action similarity from one another (a situation that is impossible with common objects).

It is clear from the above two studies that visual object similarity and action similarity influenced the pattern of errors for both object naming and producing actions with objects. However, in the above two studies, during test trials object naming was always done before action identification and production; participants were first asked what the object is called, and then asked what it does. Therefore, it could be argued that the previous studies with novel objects explored the indirect route of actions and not the direct route. This is because when naming objects first, access to semantics is required. So, from semantics, an action output is activated. Therefore, it is possible that naming objects before producing actions enhanced the impact of semantics on action production. Indeed, Desmarais, Pensa, Dixon & Roy (2007) showed that after an object naming error, people were more likely to produce the action associated with the wrong name more frequently than any other wrong action. Once an object is presented, an incorrect name can be followed by either the action associated with the incorrect name (1 possibility) or by another incorrect action (6 possibilities). Using a chi-square analysis, they found that participants were producing the action associated with the wrong name more frequently than predicted by chance. For example, if the object name was 'fint' and the participant called the object 'baiv', he/she performed the action that was associated with 'baiv' more frequently than predicted by chance. This suggests that naming objects first may have enhanced the impact of semantic information on action production. Therefore, if actions were produced first, this might enhance the possibility of using the direct route to actions.

Dabbagh, Desmarais, Roy and Dixon (2008 a & b) replicated the method of these novel object studies except they varied task order. Half of the participants named each object first, and then produced its associated action. The other half of participants produced the action associated with each object first, and then named the object. Results replicated previous findings: participants confused similar actions more often than dissimilar actions. Also, participants confused actions more often when they were associated with visually similar objects than when the same actions were associated with visually dissimilar objects. In addition, they expected that participants who named objects first would show a larger impact of semantic similarity on action production than participants who produced actions first. They expected this because according to the NAM (Yoon et al., 2002) names cannot be selected without accessing semantics, while actions can be selected without accessing semantics. However, this was not supported by Dabbagh et al.'s (2008 b) results. Interestingly, in the study, it was noted that some participants in the action first condition still named the objects first. This was evidenced from their verbalizations of the names even though they were encouraged to produce actions first. Hence, even for those in the action first condition who did not overtly name the objects, it is possible that they still covertly named the objects first. Another drawback in the study was that semantic similarity was not manipulated since non-word labels were used. These non-word labels did not carry any semantic information with them. Also, there might be a possibility that the direct route (connection between structural description system and action output) to action production did not exist or was weakly established since the objects were novel and participants had no prior experience with them. In addition, when participants produced actions to objects, it was not possible to determine which route; direct or indirect, they took. They could have been thinking of the action first and then naming objects or they could have been naming objects first. All of these drawbacks will be explored further and dealt with in the current study.

1.5 Current Study

Past research has established that visual object similarity and action similarity drive confusions for object naming and action production. However, the role of semantics in naming and producing actions associated with novel objects is unclear because past studies with novel objects used only non-word names. The purpose of the current study is to show that when participants first learn new object-action associations, they produce actions through an indirect route to actions (via semantics), and that after training, they use a direct route to actions as a result of potentially enhancing the direct link between the structural features of objects and their actions. Therefore, participants learned labels and actions associated with novel objects in five sessions on five separate days, and in the process they had the chance to practice these actions. Schyns (as cited in Wallis & Bulthoff, 1999) said that in order to improve the representation of a response, adequate exposure is needed. Indeed, Rumiati and Humphreys (1998) showed that familiarity correlated with the total number of errors made on gesturing to each object. When making gestures in response to line drawings of objects under a deadline of 450 ms, participants produced fewer errors in response to line drawings of familiar objects than in response to line drawings of unfamiliar objects. Similarly, Bozeat, Ralph, Patterson, and Hodges (2002) showed that when patients with semantic dementia used objects, there was a significant association between object familiarity (as rated by spouse or caregiver) and correct object use. In essence, even though these patients could generally not use objects correctly, they could use some objects correctly if they were highly familiar with them. Bozeat et al. (2002) provided two possible mechanisms for this observation. First, repeated practice facilitates the production of actions by reinforcing conceptual representations. As a result, the semantic representations of objects are enhanced which allows the patients to use the indirect route to actions. Second, repeated practice can create automatic action responses when presented with a specific object. In other words, this mechanism reflects the involvement of the direct route to actions. In addition, it could be that practice affects both mechanisms at the same time. Hence, according to the second mechanism, repeated practice might be required to develop or strengthen this direct route to action production. Therefore, participants in the current study practiced producing actions with objects so that they had the chance of strengthening this direct route to action production.

A key question for this study is how much practice is needed. Some insight to answering this question comes from a study by MacLeod and Dunbar (1988) who examined the effect of practice on enhancing the stroop effect interference in a novel task. The Stroop task usually involves a colour word (for example, red) that appears in coloured ink (Stroop, 1935). In the first experiment, Stroop asked participants to read a list of colour names and measured their mean reaction times. There were two conditions: reading colour names printed in black and reading colour names where the colour of print and word were different (for example, red with green font colour). He found that there was no significant difference in mean reaction times between the two conditions. In the second experiment, Stroop asked participants to name the colour of the word and measured their mean reaction times. There were two conditions: naming the colour of solid squares and naming the colours words were printed in, where the colour of the print and the word were different. He found that participants took significantly longer time to name colours when the colour of the print and the word were different than when the colours appeared on solid squares. Essentially, the word interfered with naming the colour, but not vice versa.

MacLeod and Dunbar (1988) adapted the stroop interference phenomenon by assigning colour names to unfamiliar shapes. Their aim was to determine if training could lead to interference in colour naming. They trained participants to associate four unfamiliar shapes with colour names. Then, they showed participants the shapes and asked them to name the colours when they appeared on shapes. They had congruent and incongruent trials. For congruent trials, each colour appeared on only the shape with the corresponding colour name (for example, if one of the shapes during training was associated with red colour name, it appeared in the red colour name in these trials. For incongruent trials, each colour appeared on each shape except the one with the corresponding colour name (for example, if one of the shapes during training appeared in the red colour, it appeared in all the other colour names except red colour name in these trials). Also, they asked participants to name the shapes when they appeared in colour. Similarly, they had congruent and incongruent trials. They varied the amount of training. They trained different participants on naming each of the four shapes for 4 times for a total of 16 trials, 48 times for a total of 192 trials, 72 times for a total of 288 trials, and 144 times for a total of 576 trials. Results after training revealed that when participants named shapes that appeared in colour, their mean reaction times were shorter for congruent trials than for incongruent trials. However, when participants named colours that appeared on shapes, their mean reaction times did not differ between congruent and incongruent trials. This pattern of results was the same across the different practice conditions. Therefore, shape identity did not interfere with colour naming for any of these training conditions. The authors speculated that this was probably due to the fact that participants needed more training sessions for the interference to occur. Therefore, they trained participants to practice naming each of the four shapes for 144 times for a total of 576 trials on each day for three days. Results showed that when participants named shapes that appeared in colour, their mean reaction times were shorter for congruent trials than for incongruent trials. Similarly, when participants named colours that appeared on shapes, their mean reaction times were shorter for congruent trials than for incongruent trials. Essentially, by training participants with enough practice sessions, the researchers induced interference in colour naming from shape identity.

Based on these findings, participants in this study had a chance to practice producing actions with objects so the direct route to action production is strengthened. Applying the same amount of practice as MacLeod and Dunbar (1988) would require 1,152 trials on each day, which would take about two hours each day. Having that many trials does not seem feasible given the potential time availability of the participants and the potential effects of fatigue. In this study, then, considering these factors participants practiced for seventy five blocks for each of the eight objects for a total of 600 trials each day for three days.

Another drawback from the previous study by Dabbagh et al. (2008 a & b) was that when participants produced actions with novel objects, it was not possible to determine if they used the direct route or indirect route to action production because there was no way of testing this directly. However, Rumiati and Humphreys (1998) asked participants to gesture in response to words corresponding to objects. They observed that when they asked participants to gesture in response to words, the errors that participants produced were semantic in nature. The researchers concluded that a semantic route is used to gesture in response to words. Similarly, according to the NAM (Yoon et al., 2002), producing actions in response to words requires access to semantics. Therefore, participants in this study produced actions with a cylinder approximating the size of the novel objects in response to their labels. Asking participants to produce actions with another novel object that is not visually related to the previously learned objects will mimic gesturing in response to words in Rumiati and Humphreys' (1998) study and will guarantee access to the indirect route to action production. Participants must produce the actions associated with the names of each of the previously learned novel objects by accessing the indirect route to action production as they will not have access to the visual representations of the objects. This task then represents a more or less pure measure of the semantic route to action production.

Another purpose of the current study is to show that when naming novel objects, participants use semantics. Recall that in Dabbagh et al. (2008 a &b) semantic similarity was not manipulated since non-word labels were used. Therefore, in the current study, participants named objects using labels with meaningful semantic information. Dixon, Bub, and Arguin (1997) used this method and paired computer generated shapes with verbal labels that were either semantically similar (hammer, saw, wrench, and screwdriver) or semantically dissimilar (shark, rose, apple, and hummingbird). They presented E.L.M., a neurological patient, with sequences of interleaved learning trials where E.L.M. saw a shape and heard its name, and test trials where E.L.M. saw a shape and was asked to remember the shape's name. Results showed that E.L.M. made more naming errors when shapes were paired with semantically similar labels than when the same shapes were paired with semantically dissimilar labels. Therefore, in this study, half of the objects were associated with semantically similar labels and the other half were associated with semantically dissimilar labels.

In order to reduce the possibility of participants naming objects first when they are supposed to produce an action, participants in this study responded by a deadline following the method in the Rumiati and Humphreys's (1998) study. Imposing a deadline should bias participants to use the most time efficient route to produce actions. The Rumiati and Humphreys' study used a deadline of 450 ms for participants to name objects and they used the same deadline for participants to produce actions with objects. Since novel objects were used in this study, a 450 ms deadline would likely be too short. The objects that were used in this study were novel and relatively more difficult to distinguish than known objects.

Behavioural data provides some insight into the time that is required to initiate a naming or gestural response to novel objects. Desmarais and Dixon

(2006) asked participants to learn to name novel 2-D shapes similar to those used here with the labels of similar birds (e.g., robin, sparrow) and dissimilar birds (e.g., ostrich, penguin). After learning the shape-label associations, the researchers presented participants with a shape and a cross at one of the four corners of the screen. In half of the trials, the vertical arm of the cross was longer, and in the other half the horizontal arm was longer. Participants named the shape as fast as possible, and indicated which arm of the cross was longer. Results revealed that participants named novel shapes associated with the names of similar birds in about 1200 ms. On the other hand; participants named novel shapes associated with the names of dissimilar birds in about 1100 ms. The reaction times in the study were for naming 2-D shapes presented on a computer screen. The objects that were used in this study have a similar structure, but are 3-D, where participants named and produced actions with the actual objects. Therefore a deadline of 1200 ms for executing actions and naming these objects would seem appropriate.

The main aim of this thesis is to investigate the nature of errors in object naming and producing actions in response to novel objects before and after practicing object-action associations. Since half of the objects were associated with semantically similar labels and the other half were associated with semantically dissimilar labels, there were four types of confusions that a participant could make:

1- Confusing an object associated with a semantically similar label with another object associated with a semantically similar label (similar confusion).
2- Confusing an object associated with a semantically similar label with another object associated with a semantically dissimilar label.
3- Confusing an object associated with a semantically dissimilar label with another object associated with a semantically similar label.

4- Confusing an object associated with a semantically dissimilar label with another object associated with a semantically dissimilar labels (dissimilar confusion).

The current study focused on comparing confusions between two novel objects associated with the names of similar labels and confusions between two objects associated with the names of two dissimilar labels (first and fourth type of confusions). The following is a summary of predicted data for the three deadline conditions before and after practice.

Naming Errors:

Before practice, it is expected that participants will confuse novel objects associated with the names of similar labels more often than novel objects associated with the names of dissimilar labels. After practice, there will be an overall drop in errors. However, the pattern will stay the same before and after practice. Participants will still confuse novel objects associated with the names of similar labels more often than novel objects associated with the names of dissimilar labels. This is because naming requires access to semantics.

Action Errors:

Object Condition: Before practice, it is expected that participants will confuse actions associated with the names of similar labels more often than actions associated with the names of dissimilar labels. This is because participants will likely take the indirect route to action production via semantics since the direct route to action production is probably weak. After practice, there will be an overall drop in errors as predicted for the naming condition. However, in contrast to naming, there will be an equivalent number of confusions between actions associated with the names of similar labels and between actions associated with the names of dissimilar labels. This contrasting pattern will likely reflect the decreased influence of semantics on action production due to the extended practice in performing the actions linked to these novel objects.

Cylinder Condition: Before practice, it is expected that participants will confuse actions associated with the names of similar labels more often than actions associated with the names of dissimilar labels. After practice, there will be an overall drop in errors. However, unlike the novel object condition, the pattern will stay the same before and after practice. Essentially, practicing the actions associated with the novel objects should not affect performance in this condition. Because participants will produce actions with the cylinder, they will have to access semantics using the labels associated with the novel objects since the structural descriptions will not be available to them.

2.0 Method

2.1 Participants

Ten right-handed undergraduate and graduate students from the University of Waterloo (4 males, 6 females) with an average age of 22.3 years old participated in the study. Because participants were required to learn English words as labels, participants were excluded if English was not their first language. On average, it took seven hours for participants to finish the five sessions of the study.

2.2 Materials

Eight novel graspable objects (see Desmarais, Dixon, and Roy, 2007) having different combinations of curvature, tapering, and thickness were used. The objects form a three-dimensional space. Cartesian coordinates describe the position of each object in the space (Figure 2). For example, the object in position (0,0,0) is the ‘origin object’, which is basically a cucumber shaped object. All other objects involve modifications of this origin object. In this space, some objects are closer together than other objects. The distance between two objects can be interpreted as city-block (CB) distance. A city-block distance represents the sum of the distances obtained separately on each dimension. It follows then that the number of distinctive characteristics equals the number of visual CBs (VCBs) that separate two objects. For example, objects (0,0,0) and (0,0,1) are one VCB apart, whereas objects (0,0,0) and (1,0,1) are two VCBs apart, and objects (0,0,0) and (1,1,1) are three VCBs apart. Objects that are closer together are visually more similar than objects that are not as close.

Each of these objects was associated with one of eight actions that are formed by the dimensions of pulling, sliding, twisting, or a combination of them

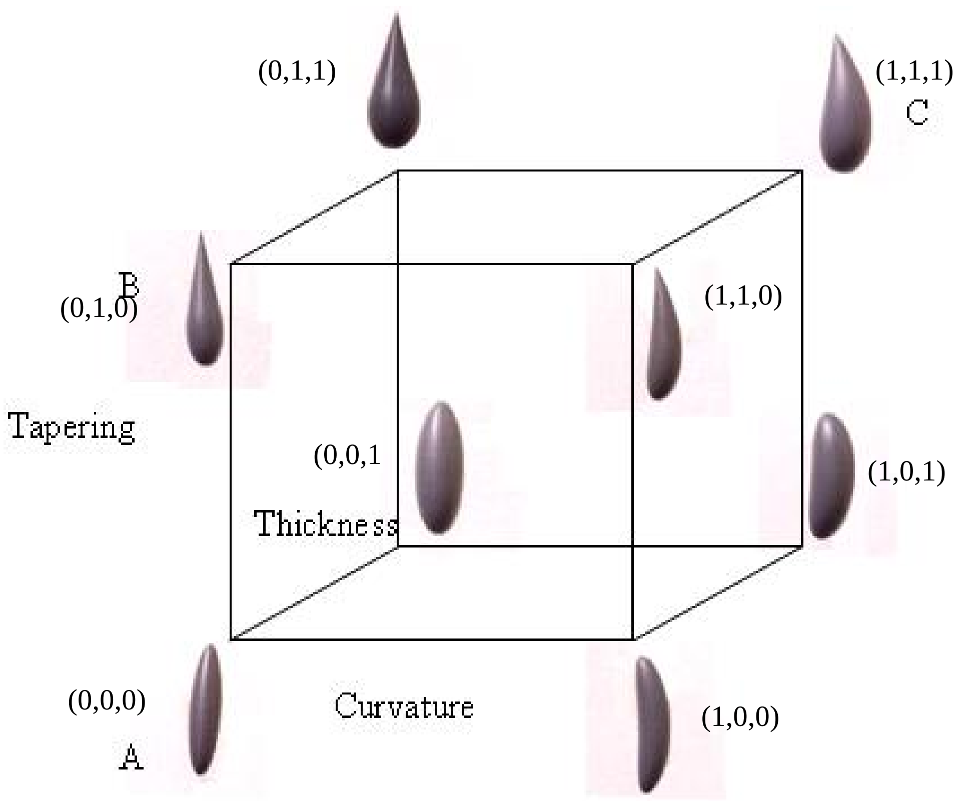

Figure 2. Three-dimensional object space. Reprinted from “A Role for Action Knowledge in Visual Object Identification,” by G. Desmarais, M. J. Dixon, and E. A. Roy, 2007, *Memory and Cognition*, *35 (7)*, p. 1713, Copyright 2007 by the Psychonomic Society, Inc. Reprinted with permission.

(see Desmarais, Dixon, and Roy, 2007). Similar to the object space, these actions form a three-dimensional space. Cartesian coordinates describe the position of each action in the space (Figure 3). For example, the action in position (0,0,0) is called the ‘origin action’, which is basically grasping an object. All other actions involve modifications of this origin action. Similar to the object space, some actions are closer together than other actions, and the distance between two actions can be interpreted as city-block (CB) distance The number of distinctive characteristics equals the number of action CBs (ACBs) that separate two actions. For example, actions (0,0,0) and (0,0,1) are one ACB apart, whereas actions (0,0,0) and (1,0,1) are two ACBs apart, and actions (0,0,0) and (1,1,1) are three ACBs apart. Actions that are closer together are visually more similar than actions that are not as close.

Objects were mounted onto a manipulandum (Figure 4) that allowed users to move the object by sliding it 6 cm leftwards, pulling it out by 12 cm, or rotating it leftwards so that the top portion of the hand covered a 6 cm distance. There were two manipulandi used; one was placed in front of the participant and the other one was placed in front of the researcher. In addition, a modified manipulandum was used during practice sessions, where all eight objects were mounted on it (Figure 5). This modified manipulandum allowed users to move each object the same distances as the original manipulandum.

Another novel object, a cylinder, was used (Figure 6). The cylinder was approximately the same size as the eight novel objects. Also, PLATO liquid crystal glasses were worn by participants. These glasses can be instantaneously switched from clear to opaque to prevent vision between trials. When the glasses are opaque the light reaches the eye but vision is prevented. When the glasses are clear the environment is fully visible. This ensured that the presentation time of objects and actions was standardised. In addition, the

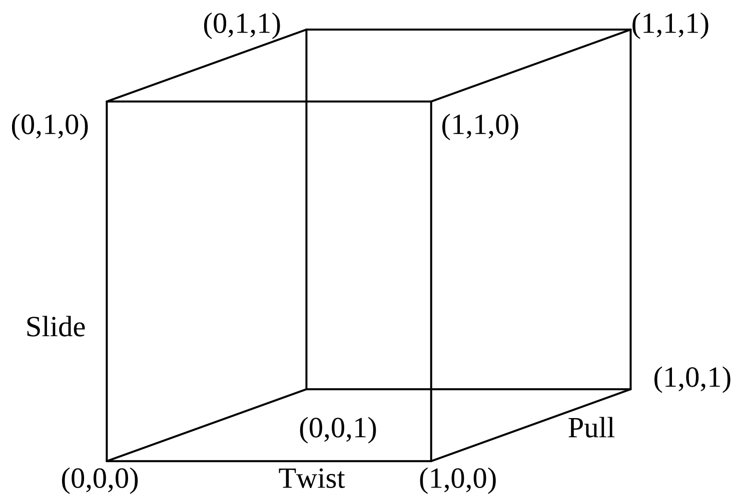

Figure 3. Three-dimensional action space. Reprinted from "A Role for Action Knowledge in Visual Object Identification," by G. Desmarais, M. J. Dixon, and E. A. Roy, 2007, *Memory and Cognition, 35 (7)*, p. 1715, Copyright 2007 by the Psychonomic Society, Inc. Reprinted with permission.

Figure 4. Manipulandum.

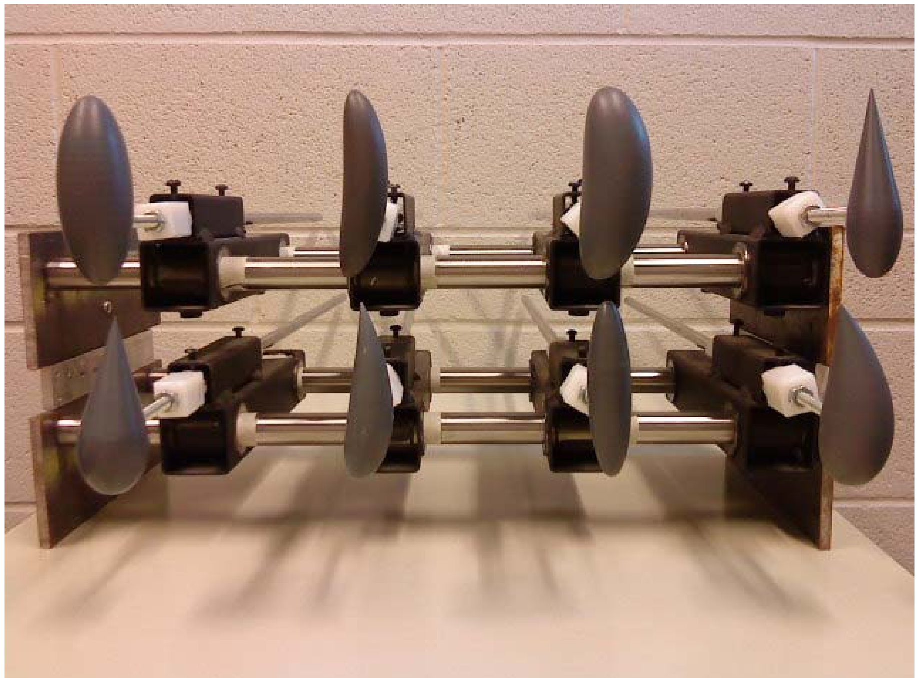

Figure 5. Modified Manipulandum.

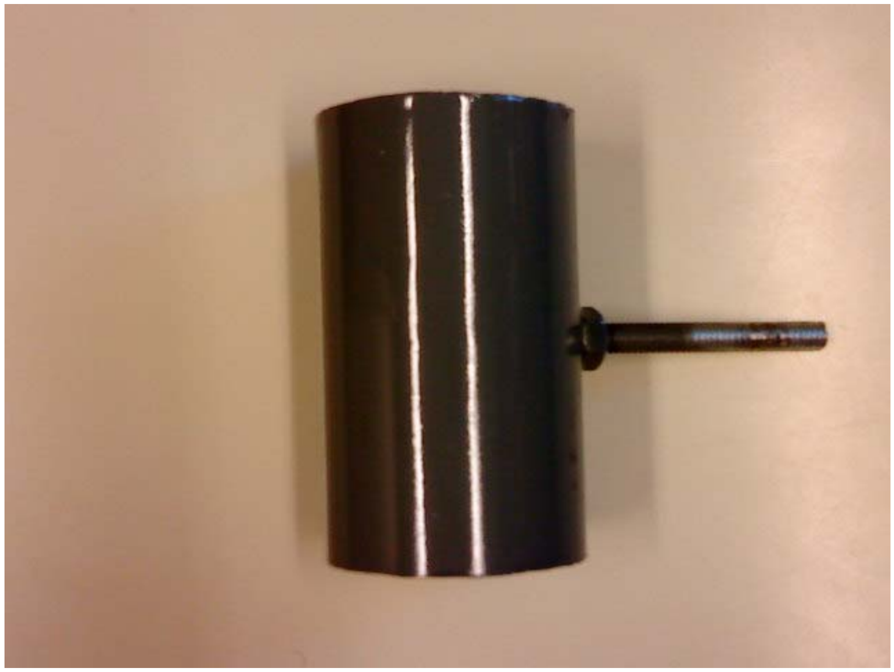

Figure 6. Cylinder.

switching of the glasses from clear to opaque served as the deadline that participants were encouraged to respond by.

Eight labels were used as the names of the eight objects. Four of the labels were semantically similar [robin (2, 5.95), crow (3, 5.00), sparrow (1, 4.35), chickadee (1, 3.80)] and the other four were semantically dissimilar [milk (49,-), guitar (22, 6.15), sweater (18, 8.45), sand (29,-)]. The first number between brackets corresponds to the Kucera and Francis (1967) frequency and the second number corresponds to familiarity ratings (McRae, K., n.d.). However, the frequencies for 'milk' and 'sand' correspond to the MRC psycholinguistic database (Wilson, 1988). The mean frequency for the semantically similar labels is 1.75 and for the semantically dissimilar labels is 29.5; t (6) = - 4.020, p = 0.007. Since the semantically similar labels have lower mean frequency than the semantically dissimilar labels, then this potentially enhances the effect of semantic similarity on object naming and action production. This is because it will be more likely to produce more errors for objects associated with semantically similar labels than objects associated with semantically dissimilar labels. Therefore, for the three tasks in this study, there might be an enhancement of the differences between semantically similar and semantically dissimilar labels. However, this will provide a stronger test for the effect of semantic similarity on producing actions with novel objects after practice. It is expected that in this task, participants will make equivalent number of errors for objects associated with semantically similar labels and objects associated with semantically dissimilar labels. Therefore, if this prediction holds then that shows that practicing object-action associations had such a strong influence on decreasing the influence of semantic similarity on action production with novel objects after practice such that there was no influence of frequency. In essence, this difference in the mean frequencies will result in more difficulty in finding equivalent number of errors for objects associated with semantically similar labels and objects associated with semantically dissimilar labels. The mean familiarity for the semantically similar labels is 4.8 and for the semantically dissimilar labels is 7.3; t (4) = - 2.555, p = 0.063. The associations between novel objects, actions, and labels were counterbalanced between participants (see Table 1 in the Appendix A).

It is important to note that for every two participants, the action associations with the novel objects were the same and the order of testing conditions on the first and the last session was the same. The only difference between these two participants was that the objects that were associated with semantically similar labels for one participant; were the same objects that were associated with semantically dissimilar labels for the other participant. This controlled for visual object and action similarity and ensured that any differences found between the two conditions will result from differences in associating the novel objects with similar versus dissimilar labels.

2.3 Procedure

Participants were asked to learn the labels and actions associated with each novel object. Participants completed one session per day on each of five separate consecutive days, except for one participant who did the third and the fourth session on the same day.

2.3.1 Day 1 and Day 5

Introduction to objects, names and actions:

Because there were eight different labels, the researcher asked participants to memorize them before being presented with objects and their associated labels and actions. The researcher read the list of eight labels, and asked the participants to recall as many as they could in any order. After that, the researcher read the list again and the participants recalled the labels. This continued until participants remembered all eight labels correctly twice in a row. This ensured that errors produced later on were due to confusion with regard to semantic similarity and not simply due to not remembering a label. Next, participants learned to associate each novel object with a name and an action. This learning process involved a series of interleaved binding and testing trials.

Binding Trials: At the beginning of each trial, participants' vision was occluded using PLATO liquid crystal glasses. With glasses opaque, one object was mounted by the researcher on to the participants' manipulandum and another identical object on to the researcher's manipulandum. The researcher then pressed a button that made the goggles transparent, said the object's label, and demonstrated how to use the object mounted on the manipulandum in front of her. The researcher instructed participants to listen to the label and watch the action and to remember both. The researcher then pressed a button to occlude vision with the PLATO liquid crystal glasses and mounted the next object on the manipulandi. This sequence continued until all eight objects, labels, and actions were presented once in random order.

Testing Trials: At the beginning of each trial, participants' vision was occluded. During this time, the researcher mounted an object onto the manipulandum in front of the participants. The researcher then pressed a button that made the goggles transparent, and asked the participants to say the name of the object and to produce its associated action. After the participants responded, the researcher pressed a button to occlude vision with the PLATO liquid crystal glasses and mounted the next object on the manipulandum. The researcher presented participants with each of the eight novel objects, one at a time. The participants' naming and action responses on each testing trial were recorded. No feedback was provided to the participants.

After eight of these testing trials, one for each object, participants received eight more binding trials following the procedure noted above. This interleaving of eight binding and testing trials continued until participants correctly labelled all eight objects and correctly produced all eight actions twice in a row.

Naming and producing actions to a deadline:

The next part of the session involved three tasks: (1) naming objects (2) producing actions with objects (3) producing actions with a cylinder. All three tasks were preformed under a deadline. The order of the tasks was counterbalanced between participants (see Table 2 in Appendix A).

Naming Objects (testing trials): At the beginning of each trial, participants' vision was occluded. During this time, the researcher mounted one of the objects onto the manipulandum in front of the participants. Then, the researcher pressed a button that made the goggles transparent. After 1200 ms, the glasses automatically became occluded. So, the researcher asked the participants to try saying the label of the object before 1200 ms and encouraged them to say the first label that came to their mind. Then, the researcher mounted the next object onto the manipulandum and pressed a button that made the glasses transparent. Participants were presented with each of the eight novel objects, one at a time. There were fifteen blocks of these trials for a total of 120 trials. No feedback was provided to the participants. However, every five blocks, participants received a reminder block where the researcher mounted each object on the manipulandum and named it.

Actions with novel objects (testing trials): At the beginning of each trial, participants' vision was occluded. During this time, the researcher mounted an object onto the manipulandum in front of the participants. Then, the researcher pressed a button that made the glasses transparent. The participants' right hand was always located approximately five centimetres to the right of the manipulandum. After 1200 ms, the goggles automatically became occluded. So, the researcher asked the participants to try producing the action associated with the object before 1200 ms and encouraged them to produce the first action that came to their mind. Then, the researcher mounted the next object onto the manipulandum and pressed a button that made the glasses transparent. Participants were presented with each of the eight novel objects, one at a time. There were fifteen blocks of these trials for a total of 120 trials. No feedback was provided to the participants. However, every five blocks, participants received a reminder block where the researcher mounted each object on the manipulandum and produced its associated action.

Actions with a cylinder (testing trials): At the beginning of each trial, participants' vision was occluded. Then, the researcher mounted a cylinder onto the manipulandum in front of the participants. The participants' right hand was always located approximately five centimetres to the right of the manipulandum. After that, the researcher pressed a button that made the glasses transparent and said the label of one of the objects. After 1200 ms, the glasses automatically became occluded. So, the researcher asked the participants to try producing the action on the cylinder that was associated with the novel object corresponding to the given label before 1200 ms and encouraged them to produce the first action that came to their mind. Then, the researcher pressed a button that made the goggles transparent once again and said the next label of the object. Participants were given the labels with each of the eight novel objects, one at a time. There were fifteen blocks of these trials for a total of 120 trials. No feedback was provided to participants. However, every five blocks, participants received a reminder block where the researcher mounted the cylinder on the manipulandum in front of her, said the label of one of the previously learned novel objects and then produced its associated action.

2.3.2 Days 2, 3, 4

On days 2, 3, and 4, participants practiced producing the actions that were associated with each object; naming was not practiced. First, participants were given a block of reminder trials, where the researcher mounted each of the eight novel objects on the manipulandum placed in front of her, and showed their associated actions. One novel object was shown at a time. After the block of the reminder trials, the researcher pointed to one of the objects on the modified manipulandum placed in front of the participants and asked them to show its associated action. The physical location of the objects was different for the three practice sessions (see Table 3 in Appendix A). This was done so that participants did not become accustomed to associate an object with a specific location on the modified manipulandum. When participants made a mistake, the researcher informed them that a mistake was done and asked them to attempt to produce the correct action again. Participants practiced for 75 blocks for each of the eight objects for a total of 600 trials each day excluding the block of reminder trials.

3.0 Results

3.1 Data Analysis

When participants said a wrong label, the researcher coded which two labels were confused. For example, if the objects' label was 'robin' and the participant said 'crow'; the researcher coded this error as confusion between semantically similar labels. On the other hand, if the objects' label was 'milk' and the participant said 'sand'; the researcher coded this error as confusion between semantically dissimilar labels. Also, when participants produced a wrong action with the novel objects and with the cylinder, the researcher coded which two actions were confused. For example, if the object's action was associated with a semantically similar label (such as robin) and the participant produced incorrect action of another object associated with a semantically similar label (such as crow); the researcher coded this error as confusion between actions associated with semantically similar labels. On the other hand, if the object's action was associated with a semantically dissimilar label (such as milk) and the participant produced incorrect action of another object associated with a semantically dissimilar label (such as sand); the researcher coded this error as confusion between actions associated with semantically dissimilar labels. A repeated measures ANOVA was conducted since each participant participated in all of the different conditions of the study for the factors of condition, time, and type of confusion. An alpha level of 0.05 was used. In addition, a series of planned comparisons of one tailed paired t-tests were used in order to compare the impact of semantic similarity on the three deadline tasks before and after practice.

3.2 Findings

As a first step, an analysis was performed on blocks to criterion for naming objects and producing actions with objects in order to compare the level of difficulties of the two tasks. Also, this analysis was performed in order to see if introducing these object-label-action associations again after practice served only as a reminder. That is, participants did not need to relearn the associations again. A 2 task (naming, actions) x 2 practice (before, after) ANOVA was performed. Results showed no main effect of task; $F(1,9) = 2.647$, $p = 0.138$. This means that the two tasks were comparable in difficulty. There was a main effect of practice; $F(1,9) = 38.157$, $p < 0.001$. In general, after practice (mean = 2, SD = 0), participants took less number of blocks to name objects and produce their associated actions correctly twice in a row compared to before practice (mean = 5.55, SD = 1.82). The significance of a main effect of practice is not surprising. Before practice, participants performed the tasks with no prior exposure. On the other hand, after practice, participants performed the tasks after they had already learned object-label-action associations. Indeed, after practice, participants did not need to relearn the object-label-action associations. It is interesting to note that during practice days, participants made very few action errors with novel objects. Participants' overall error rates were 0.62 % on the first day of practice, 0.65 % on the second day of practice, and 0.48 % errors on the third day of practice.

Next, an analysis was conducted for the three deadline tasks. A 3 task (naming, actions with novel objects, and actions with cylinder) x 2 time (before practice, after practice) x 2 semantic similarity (similar, dissimilar) repeated measures ANOVA was conducted[1]. The analysis showed a main effect of time; F (1,9) = 89.934, p < 0.001. Generally, participants made more errors before practice (mean = 6.35, SD = 2.02) than after practice (mean = 3.267, SD = 1.41). Also, there was a main effect of confusion; F (1,9) = 34.972, p < 0.001, which means participants made more similar confusions (mean = 6.033, SD = 2.15) than dissimilar confusions (mean = 3.583, SD = 1.34). Also, there was an interaction between task and time; F (2,18) = 9.783, p = 0.001. In addition, there was an interaction between time and semantic similarity; F (1,9) = 20.242, p =0.001. Most importantly, there was an interaction between task, time and semantic similarity; F (2,18) = 7.133, p = 0.005, which was expected.

In order to determine the source of the three way interaction, a separate 2 time (before practice, after practice) x 2 semantic similarity (similar, dissimilar) repeated measures ANOVA for each task was performed. The task of naming was first analyzed (Figure 7). The analysis revealed a main effect of time; F (1,9) = 10.917, p = 0.009. Participants produced more naming errors before practice (mean = 5.7, SD = 2.60) than after practice (mean = 4.35, SD = 2.11). There was a main effect of semantic similarity; F (1,9) = 22.224, p = 0.001. Participants made more naming errors for similar confusions (mean = 6.4, SD = 2.68) than dissimilar confusions (mean = 3.65, SD = 2.20). However, there was no interaction; F (1,9) = 1.976, p = 0.193. Next, the task of actions with the cylinder was analyzed (Figure 8). Again, the analysis revealed a main effect of time; F (1,9) = 29.16, p < 0.001. Participants produced more action errors before practice (mean = 5.35, SD =1.31) than after practice (mean = 3.1, SD = 1.61). There was also a main effect of semantic similarity; F (1,9) =

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[1] It is worth noting that the analysis was repeated without the data from the participant who finished the third and fourth sessions on the same day and the pattern of results remained the same. Therefore, the analysis presented includes data from all participants.

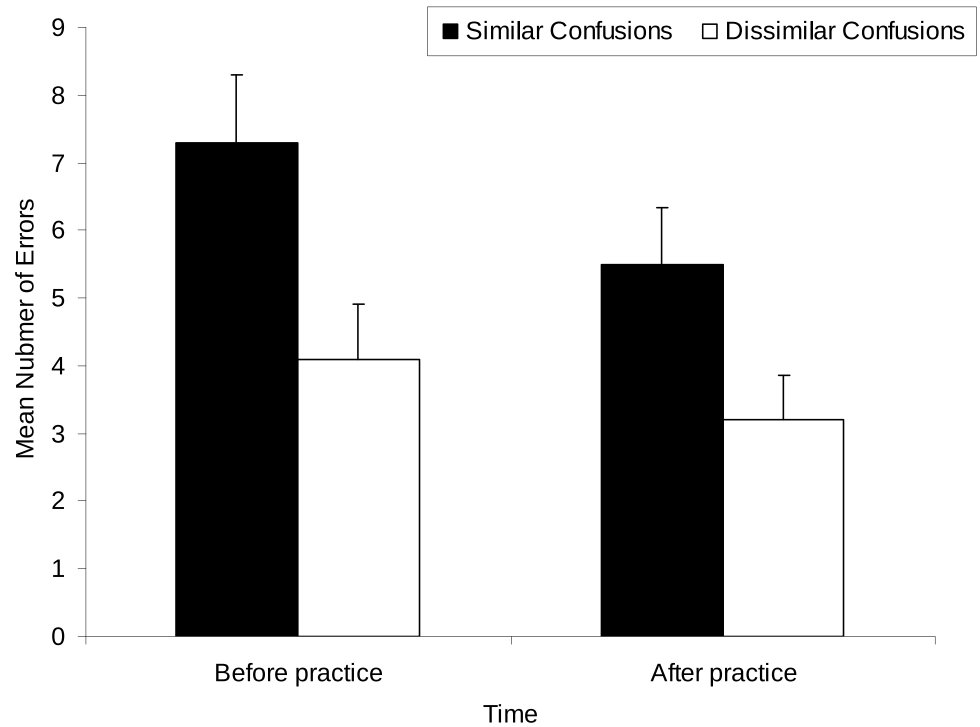

Figure 7. Mean number of naming novel objects errors to type of confusion as a function of time.

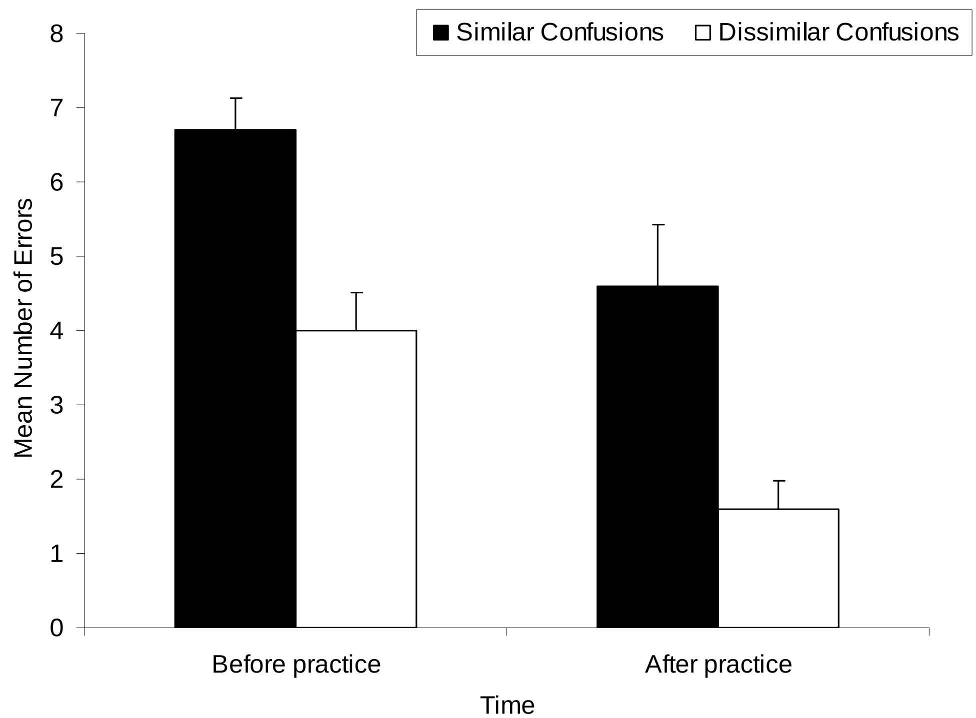

Figure 8. Mean number of actions with cylinder errors with to type of confusion as a function of time.

52.123, $p < 0.001$. Participants made more action errors for similar confusions (mean = 5.65, SD = 1.63) than dissimilar confusions (mean = 2.8, SD = 1.25). However, there was no interaction; F (1,9) = 0.088, p = 0.774. Finally, the task of actions with the novel objects was analyzed (Figure 9). Again, the analysis revealed a main effect of time; F (1,9) = 31.051, $p < 0.001$. Participants produced more action errors before practice (mean = 8.0, SD = 3.43) than after practice (mean = 2.35, SD = 0.97). There was also a main effect of semantic similarity; F (1,9) = 10.97, p = 0.009. Participants made more action errors for similar confusions (mean = 6.05, SD = 2.64) than dissimilar confusions (mean = 4.3, SD = 1.47). However, there was an interaction between time and semantic similarity; F (1,9) = 21.0, p = 0.001. When participants produced actions before practice, they made more errors for similar confusions (mean = 10.1, SD = 4.91) than dissimilar confusions (mean = 5.9, SD = 2.18); t (9) = 4.075, p = 0.001. However, when participants produced actions after practice, they no longer made more errors for similar confusions (mean = 2.0, SD = 0.94) than dissimilar confusions (mean = 2.7, SD = 1.16); t (9) = - 2.689, ns (one-tailed test). In summary, the three way interaction arises from the significant interaction between time and semantic similarity for the task of producing actions with the novel objects, while this interaction is not significant for naming objects and producing actions with the cylinder in response to object labels.

It is important to note that the results of the above analysis compared confusions between two different sets of actions. So, for the three tasks, it compared confusions between objects or actions associated with semantically similar labels and objects associated with semantically dissimilar labels. For example, a similar confusion between robin and chickadee is at the same time confusion between actions of hold and pull. A dissimilar confusion between

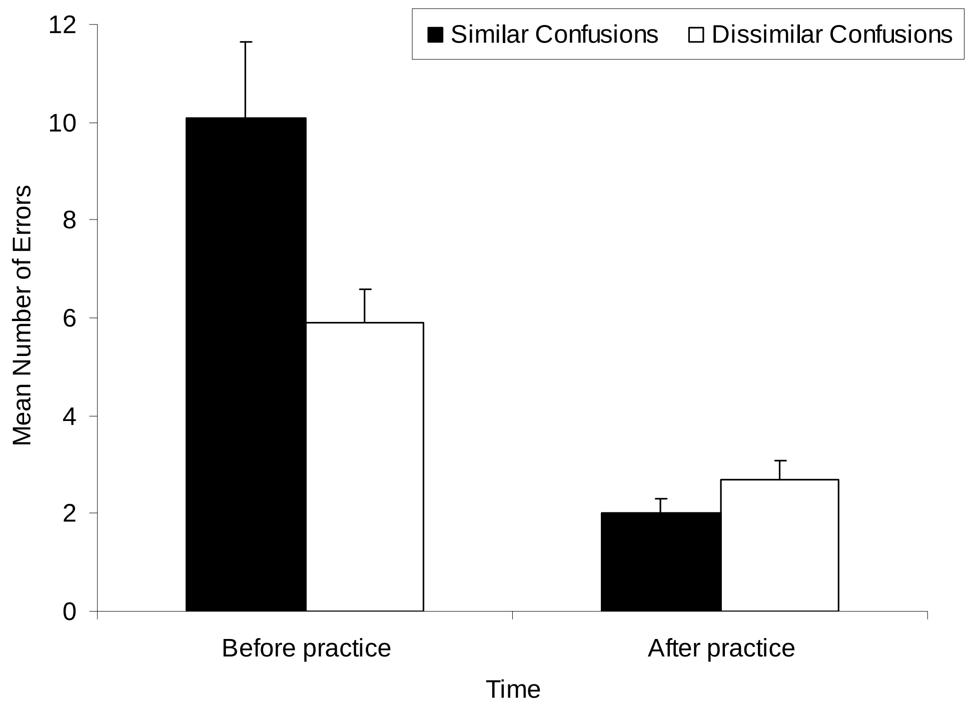

Figure 9. Mean number of actions with novel objects errors to type of confusion as a function of time.

milk and guitar is at the same time confusion between actions of slide and slide and twist. In essence, similar and dissimilar confusions involve different actions. Another way of testing the influence of semantic similarity on action production is to compare confusions between the same set of actions. Therefore, for the three tasks, this second analysis compared how often participants confused objects associated with semantically similar labels to (a) other objects associated with semantically similar labels versus (b) objects associated with semantically dissimilar labels. For example, a similar confusion between robin and chickadee is at the same time confusion between actions of hold and pull. But, now a dissimilar confusion between robin and milk is at the same time confusion between hold and slide. In essence, similar and dissimilar confusions involve the common action of hold. Results of this second analysis showed similar pattern of results for the three tasks (for more details, please see Appendix B). The fact that both analyses showed similar results provides a strong support for the conclusions in this study.

4.0 Discussion

One of the aims of this study was to show that practicing actions with the novel objects will decrease the reliance on semantics when producing these actions. Another aim of the study was to show that naming novel objects and producing actions with the cylinder will rely heavily on semantics both before and after practicing object-action associations. The results of this study fit well with the three predictions for naming errors and action errors with the cylinder and with the novel objects. Results showed that when naming objects, participants confused objects associated with semantically similar labels more often than objects associated with semantically dissimilar labels. This pattern was the same before and after practice. Similarly, when producing actions with the cylinder, participants confused actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. This pattern was the same before and after practice. Importantly, when producing actions with the novel objects before practice, participants confused actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. However, after practice, participants did not confuse actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. Overall, the results of the current study are in agreement with its two aims.

4.1 Naming and Producing Actions with Novel Objects

The results of this study are in line with the predictions from the Naming and Action Model; NAM (Yoon et al., 2002), that was explained earlier. According to the NAM, when naming objects, access to semantics is required. However actions can be produced with access to semantics; through the indirect route, or without access to semantics; through the direct route. In this study, the influence of semantics was assessed through the use of similar (bird) labels and dissimilar (non-bird) labels. For the task of naming objects; both before and after practice, participants confused objects associated with semantically similar labels more often than objects associated with semantically dissimilar labels. According to the NAM, the only way to name objects is by accessing semantics, so this means that participants in this study were using semantics when naming objects. For the task of producing actions with the cylinder; both before and after practice, participants confused actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. According to the NAM, the only way to produce an action in response to its name is by accessing semantics, so this means that participants were using semantics (indirect route to action production) when producing actions with the cylinder. For the task of producing actions with the novel objects; before practice, participants confused actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. This suggests that participants seemed to be using the indirect route to action production when producing actions with the novel objects before practice. On the other hand, after practice, participants did not confuse actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. This suggests that participants seemed to be using the direct route to action production when producing actions with the novel objects after practice. Overall, the pattern of results suggests that semantic similarity influenced the tasks of naming objects and producing actions with the cylinder both before and after practice. However, semantic similarity influenced the task of producing actions with the novel objects before practice but not after practice.

The observation that semantic similarity influenced naming objects both before and after practice confirms the findings by Rumiati and Humphreys (1998) who asked healthy participants to name line drawings of objects. They found that most of the naming errors produced were semantic in nature and concluded that naming objects requires access to semantics. Similarly, the pattern of results for naming novel objects in this study confirms the conclusions that were drawn by Hillis and Caramazza (1995) who tested a patient with optic aphasia, and Hodges et al. (2000) who tested nine patients with semantic dementia. They found that patients were impaired at naming line drawings of objects, and that most of the errors were semantic in nature. Overall, the pattern of results observed in the naming task confirms the notion that access to semantics is required when naming objects: participants consistently confused objects associated with semantically similar labels more often than objects associated with semantically dissimilar labels.

The observation that semantic similarity influenced producing actions with the cylinder both before and after practice confirms the findings by Rumiati and Humphreys (1998) who asked participants to gesture in response to words corresponding to objects. They showed that all of the errors were semantic in nature. The researchers concluded that a semantic route is used to gesture in response to words. In this study, the pattern of results observed when producing actions with the cylinder confirms the notion that access to semantics is required when producing actions in response to words. This result demonstrated that participants could not access the direct route to action production since the cylinder was not visually related to the previously learned novel objects. Overall, the results of this study suggest that participants were using the indirect route to action production when producing actions with the cylinder: participants consistently confused actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels.

The observation that semantic similarity influenced action production with the novel objects before practice confirms the findings by Schwartz et al.

(1995) who tested apraxic patient M.M. on gesture production. They showed that M.M. made errors with his left hand that involved substituting a conceptually related, but incorrect object. They concluded that semantics might play a role in action production. In this study, the pattern of results observed when producing actions with the novel objects before practice confirms the notion that actions are hugely influenced by semantics and participants were likely using the indirect route to action production: participants consistently confused actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. The observation that semantic similarity did not influence action production with the novel objects after practice confirms the findings by Rumiati and Humphreys (1998) who asked healthy participants to make gestures in response to line drawings of objects. They found that most of the action production errors were visual in nature. In this study, the pattern of results observed when producing actions with the novel objects after practice confirms the notion that actions are not hugely influenced by semantics and participants were likely using the direct route to action production: participants did not confuse actions associated with semantically similar labels more often than actions associated with semantically dissimilar labels. Overall, the results of this study suggest that when learning novel actions, semantics is involved heavily. On the other hand, when producing well-learned actions, the involvement of semantics diminishes.

4.2 Need for Practice to Develop Direct Route to Actions

The fact that participants were not influenced by semantic similarity when producing actions with novel objects after practice compared to before practice sheds light on the study by Bozeat et al. (2002). When they tested patients with semantic dementia on using objects, they found a correlation between correct object use and the familiarity of the object. Patients who are familiar with some objects have likely received more extensive exposure to them and so they can correctly demonstrate the use of these objects. Bozeat et al. (2002) provided two possible mechanisms for this observation. The first one deals with the role of repeated practice in strengthening degraded semantic representations. In other words, this mechanism strengthens the indirect route to action production. The second mechanism deals with the role of repeated practice in creating automatic action responses when presented with an object. In other words, this mechanism reflects the involvement of the direct route to action production. Indeed, the results of the current study showed that repeated practice seems to strengthen the direct route to action production since participants were not affected by the semantic similarity after practice compared to before practice when producing actions with novel objects. However, it is important to note that the current study did not deal with the first mechanism, so it is still possible that repeated practice might have a role in strengthening semantic representations as well. To confirm this possibility, neurological patients with semantic impairments need to be tested. In general, the results of this current study suggest that repeated practice strengthened the direct link between representations of objects in the structural description system and their action outputs.

4.3 Interaction between Two Routes to Action Production

Even though the Naming and Action Model; NAM (Yoon et al., 2002) suggests that there are two routes to action production, it is important to emphasize that these two routes are not dissociated. Indeed, Yoon et al. (2002) proposed a convergence of the two routes for action production. They suggested that separate semantic and visual representations converge to guide action selection in response to visually presented objects. The idea of the interaction between the two routes to action production is even more supported by their proposal that a lesion to one route blocks access to the second route. If the two routes to action production are dissociated, then a lesion to one route should not affect the second route. So, if the two routes are dissociated, then, it is expected that patients with a lesion to the direct route should be able to produce actions through the indirect route to action production. However, Chainay and Humhreys (2002 a) showed that impaired visual knowledge about objects hinders the performance of action production. They presented apraxic patients with photographs of objects, non-objects (formed from parts of two objects), action part of objects, and non-action part of objects. They asked the patients to gesture in response to these photographs. Results revealed that patients gestured correctly in response to photographs of objects more than in response to photographs of non-action part of objects. The authors argued that non-action part of objects is equivalent to an impaired visual knowledge about objects. So, participants could not produce as many correct gestures as they did in response to photographs of objects because the impaired direct route to action production blocked the access to the indirect route to action production via semantics. Therefore, the results of the current study suggest that when learning novel actions, the indirect route to action production via semantics is used. On the other hand, after repeated practice of producing actions with objects, the direct route to action production dominates the activity of the indirect route to action production. This means that actions are not produced only via the direct route to action production.

In addition to proposing the two routes to action production, Yoon et al. (2002) acknowledged that the direct route might be more dominant than the semantic route since it is faster; it bypasses the semantic system. Indeed, Chainay and Humphreys (2002 b) showed that participants made faster action decisions in response to objects than to words. They showed participants words and line drawings of known objects and asked them to make action decisions as to whether pouring or twisting was associated with the words and the objects. In one condition, they asked participants to move a simple manipulandum horizontally to represent a twisting action and vertically to represent a pouring action. Results showed that participants produced actions in response to words in 1,174 ms, while they produced actions in response to objects in 1, 052 ms. Producing actions in response to words is similar to producing actions with the cylinder in response labels in the current study. So, this corresponds to using the indirect route to action production. Also, producing actions in response to objects is similar to producing actions with the novel objects after practice in the current study. So, this corresponds to using the direct route to action production. Although the current study did not look at reaction time data, it seems that producing actions via the direct route is faster than producing actions via the indirect route. In essence, after practice, participants produced actions with the novel objects via the most time efficient route; namely the direct route. Therefore, participants were able to produce actions with the novel objects before semantic activity could interfere.

4.4 Role of Semantics in Action Preparation and Production

So far, it is clear that the two routes to action production are connected. However, one might wonder about the specific role of semantics in action preparation and production. Glover and Dixon (2002) showed that when grasping an object, semantics affect the planning process, but not the online control process. Participants sat in front of a mirror that allowed them to see a table with a target object. This was done in order to control the visibility of the target object on the table. There were three different sizes of target objects and they had either ‘large’ or ‘small’ labels written on them. Participants were instructed to reach out and grasp each object and to ignore the label. The researchers measured grip aperture during the reaching movement. Results demonstrated that there was a varied effect of words on grip aperture. More specifically, semantics affected planning the reaching and grasping components of objects, but this effect decreased over time. For example, if the target object had a ‘large’ label, participants would start to have a larger grip aperture than what was required. However, participants gradually would change their grip aperture to match the size of the object. The authors suggested that on-line control corrected the semantic effect during planning. In the current study, although semantics might have influenced producing actions with the novel objects after practice, it was not possible to show this minor influence of semantics. This is because the set up of the current study did not allow for testing the influence of semantics during action planning and action production separately. The pattern of results of the current study points to influence of semantics or no influence of semantics.

van Elk, van Schie, and Bekkering (2008) showed a modulation of semantic activation when preparing for action production. They asked participants to sit in front of a computer screen with a magnifying glass on one side of the table and a cylinder on the other side. At the beginning of each trial, participants pressed a start button, and a picture of one of the two objects was shown on the computer screen to indicate which object they would perform the action with. After that, a word was presented and participants had to decide whether the word represented a body part or an animal by lifting their index or middle finger. In separate blocks, participants were asked to grasp the object to perform meaningful or meaningless action. An example of a meaningful action was to bring the cup to the mouth. An example of a meaningless action was to bring the cup to the eye. The authors analyzed the N400 component (300-500 ms) after the presentation of the word. Results showed that when participants prepared a meaningful action, words that were incongruent with the action goal caused a larger semantic activation than words that were congruent with the action goal. For example, when they were instructed to bring a cup to their mouth, the presentation of the word ‘eye’ caused a larger semantic activation than when the presented word was ‘mouth’. However, when participants prepared a meaningless action, there was no difference in the semantic activation between words that were congruent or incongruent with the action goal. Similarly, van Elk, van Schie, and Bekkering (2009) used a similar paradigm described above, but instead of the presentation of a word, they presented line drawings of body parts or animals. Participants were instructed to release the start button and perform the action with the object that was previously shown on the computer screen. The authors calculated reaction times in response to the line drawings. Results showed that for meaningful actions, participants initiated actions faster in response to line drawings that were congruent with the action goal. For example, when they were instructed to bring a cup to the line drawing of mouth, they were faster when the line drawing of mouth would appear. On the other hand, for meaningless actions, participants initiated actions slower in response to line drawings that were congruent with the action goal. For example, when they were instructed to bring a cup to the line drawing of eye, they were slower when the line drawing of mouth would appear. These results provide evidence to the convergent route model proposed by Yoon et al. (2002) with semantics playing a role in action production with known objects. In the current study, there was probably some sort of involvement of semantics in the two action production tasks both before and after practice. So, future studies using reaction time or neural data might provide more insight into the modulation of the role of semantics on action production.

5.0 Future Directions

The results of this study provide promising insights into the possibility of using practice in order to help neurological patients. On a broader level, the results illustrate that with practice, healthy young people could decrease their reliance on semantic information when producing actions with objects. This observation provides a potential study to determine if using practice will help neurological patients; such as apraxic patients, in producing actions. A crucial part to this research will be to determine the sufficient amount of practice that will be needed to show significant improvements, if any, in action production. In addition, it would be interesting to see if practicing naming of objects will improve the naming performance of healthy people because in the current study, participants did not practice naming objects. If such improvement is observed, then it would be interesting to find out if patients with semantic impairments will benefit from practicing naming objects.

6.0 Conclusion

This study demonstrated that extensively practicing actions with novel objects decreased the influence of semantics when producing actions with novel objects. However, this practice did not change the influence of semantics when naming these novel objects and when producing actions with a cylindrical object. The results are in line with models that propose naming requires access to semantics and producing actions can be done with semantics; indirect route, or without semantics; direct route. In addition, the results of the study demonstrated that the direct route to action production seems to be strengthened after practicing object-action associations. The results offer new insights into possibly using practice to help neurological patients in producing actions.

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Appendix A

Table 1: Object-label-action associations for participants (h: hold, t: twist, s: slide, st: slide + twist, p: pull, pt: pull + twist, ps: pull +slide, pst: pull + slide + twist)

Note: 'I' and 'II' refer to the version of assigning labels to objects

	Shape	1,1,1	1,1,0	101	1,0,0	0,1,1	0,1,0	0,0,1	0,0,0
1	Action	h	t	s	st	p	pt	ps	pst
I	Name	Chickadee	Sparrow	Milk	Guitar	Crow	Robin	Sand	Sweater
II		Milk	Guitar	Chickadee	Sparrow	Sand	Sweater	Crow	Robin
2	Action	pst	ps	pt	p	st	s	t	h
I	Name	Sparrow	Chickadee	Milk	Guitar	Robin	Crow	Sweater	Sand
II		Milk	Guitar	Sparrow	Chickadee	Sweater	Sand	Robin	Crow
3	Action	p	pt	ps	pst	h	t	s	st
I	Name	Sparrow	Chickadee	Sweater	Sand	Robin	Crow	Guitar	Milk
II		Sweater	Sand	Sparrow	Chickadee	Guitar	Milk	Robin	Crow
4	Action	pst	ps	pt	p	st	s	t	h
I	Name	Crow	Robin	Guitar	Sweater	Sparrow	Chickadee	Sand	Milk
II		Guitar	Sweater	Crow	Robin	Sand	Milk	Sparrow	Chickadee
5	Action	h	t	s	st	p	pt	ps	pst
I	Name	Robin	Crow	Sand	Sweater	Chickadee	Sparrow	Milk	Guitar
II		Sand	Sweater	Robin	Crow	Milk	Guitar	Chickadee	Sparrow

Table 2: Order of testing deadline tasks on days 1 and 5 (N: naming, A: actions with novel objects, AC: actions with cylinder)

Participant	**Version**	**Day 1**			**Day 5**		
1	**I**	N	A	AC	A	AC	N
2	**II**	N	A	AC	A	AC	N
3	**I**	N	AC	A	AC	A	N
4	**II**	N	AC	A	AC	A	N
5	**I**	A	N	AC	N	AC	A
6	**II**	A	N	AC	N	AC	A
7	**I**	AC	N	A	N	A	AC
8	**II**	AC	N	A	N	A	AC
9	**I**	AC	A	N	A	N	AC
10	**II**	AC	A	N	A	N	AC

Table 3: Side view of physical location of objects on modified manipulandum for three practice days; P1, P2 and P3 [O: (0,0,0), C: (1,0,0), T: (0,1,0), F: (0,0,1), CT: (1,1,0), CF: (1,0,1), TF: (0,1,1), CTF: (1,1,1)]

Participant	Version	P1				P2				P3			
1 and 2	I and II	O	T	CF	TF	F	CF	CT	T	CT	O	CTF	C
		CTF	F	CT	C	TF	C	O	CTF	F	T	TF	CF
3 and 4	I and II	T	TF	CTF	CT	CF	O	TF	C	CTF	CT	T	F
		C	CF	F	O	CT	CTF	T	F	CF	TF	O	C
5 and 6	I and II	CF	CTF	C	F	TF	C	CT	CTF	CT	T	O	CF
		T	O	CT	TF	F	T	CF	O	TF	C	F	CTF
7 and 8	I and II	F	O	T	C	CTF	T	F	CT	CF	TF	CT	O
		CT	CTF	CF	TF	O	TF	C	CF	T	C	CTF	F
9 and 10	I and II	CTF	F	CT	CF	T	CT	C	O	F	C	TF	CTF
		O	TF	C	T	CF	F	CTF	TF	CT	CF	T	O

Appendix B

This analysis compared the first and the second types of confusions that participants can make. Recall that the first type of confusion was confusing an object associated with a semantically similar label with another object associated with a semantically similar label (this will be defined here as a similar confusion). The second type of confusion was confusing an object associated with a semantically similar label with another object associated with a semantically dissimilar label (this will be defined here as a dissimilar confusion). Again, when participants said a wrong label, the researcher coded which two labels were confused. For example, if the objects' label was 'robin' and the participant said 'crow'; the researcher coded this error as confusion between semantically similar labels. On the other hand, if the participant said 'sand'; the researcher coded this error as confusion between semantically dissimilar labels. Also, when participants produced a wrong action with the novel objects and with the cylinder, the researcher coded which two actions were confused. For example, if the object's action was associated with a semantically similar label (such as robin) and the participant produced incorrect action of another object associated with semantically similar label (such as crow); the researcher coded this error as confusion between actions associated with semantically similar labels. On the other hand, if the participant produced incorrect action of another object associated with semantically dissimilar label (such as sand); the researcher coded this error as confusion between actions associated with semantically dissimilar labels.

Only a subset of the data was included in this analysis so that visual object similarity and action similarity are held constant between the two types of confusions. There are twelve possible similar confusions. Eight of these confusions are between objects that are 1 CB apart, and four are between objects that are 2 CBs apart. On the other hand, there are sixteen possible dissimilar confusions. Four of these confusions are between objects that are 1 CB apart, eight are between objects that are 2 CBs part, and four are between objects that are 3 CBs apart. Because of these differences, visual object similarity and action similarity are not constant between the two types of confusions. Therefore, for similar confusions, only four out of eight confusions that are between objects that are 1 CB apart were included in this analysis. For dissimilar confusions, only four out of eight confusions that are between objects that are 2 CBs apart were included in this analysis. The result of this selective inclusion of data is that for both similar and dissimilar confusions, there are four confusions that are between objects that are 1 CB apart, and four are between objects that are 2 CBs apart.

Similar to the previous analysis, a separate 2 time (before practice, after practice) x 2 semantic similarity (similar, dissimilar) repeated measures ANOVA for each task was performed. The task of naming was first analyzed (Figure 10). The analysis revealed a main effect of semantic similarity; $\underline{F}$ (1,9) = 21.493, $\underline{p}$ = 0.001. Participants made more naming errors for similar confusions (mean = 4.0, SD = 1.86) than dissimilar confusions (mean = 0.7, SD = 0.95). Also, there was an interaction between time and semantic similarity; $\underline{F}$ (1,9) = 12.964, $\underline{p}$ = 0.006. However the pattern of results was the same before and after practice. Therefore, when participants named objects before practice, they made more errors similar confusions (mean = 5.1, SD = 2.28) than dissimilar confusions (mean = 0.7, SD = 1.06); $\underline{t}$ (9) = 5.123, $\underline{p}$ < 0.001. Similarly, when participants named objects after practice, they made more errors for similar confusions (mean = 2.9, SD = 2.08) than dissimilar confusions (mean = 0.7, SD = 1.34); $\underline{t}$ (9) = 3.236, $\underline{p}$ = 0.005. Next, the task of actions with the cylinder was analyzed (Figure 11). The analysis revealed a main effect of time; $\underline{F}$ (1,9) = 25.138, $\underline{p}$ = 0.001. Participants produced more action errors before practice (mean = 2.05, SD =1.01) than after practice (mean = 1.15, SD =

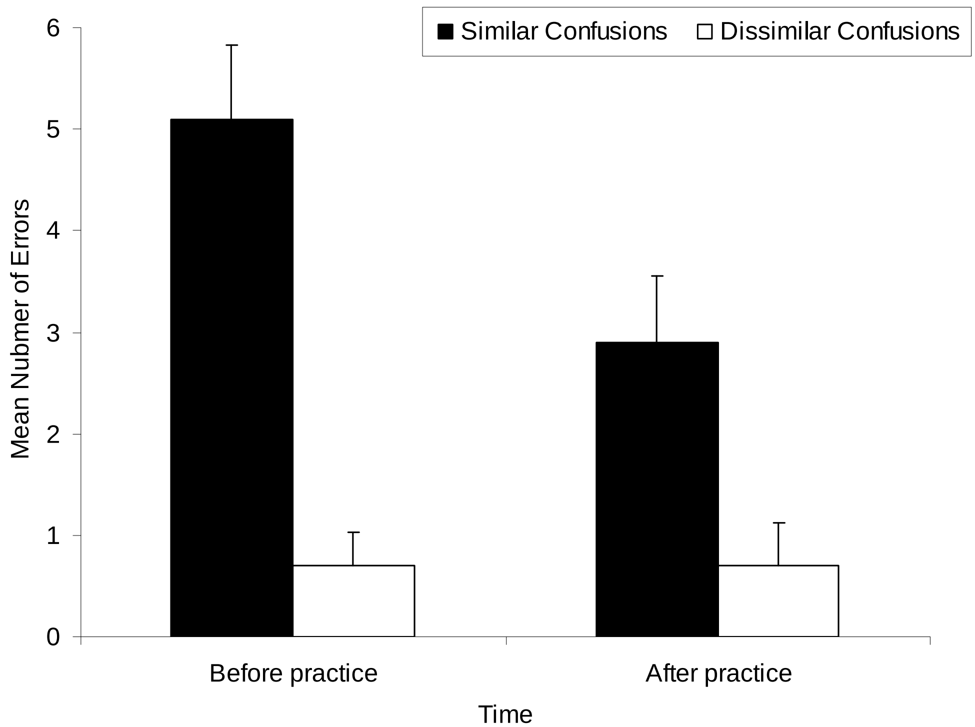

Figure 10. Mean number of naming novel objects errors to type of confusion as a function of time.

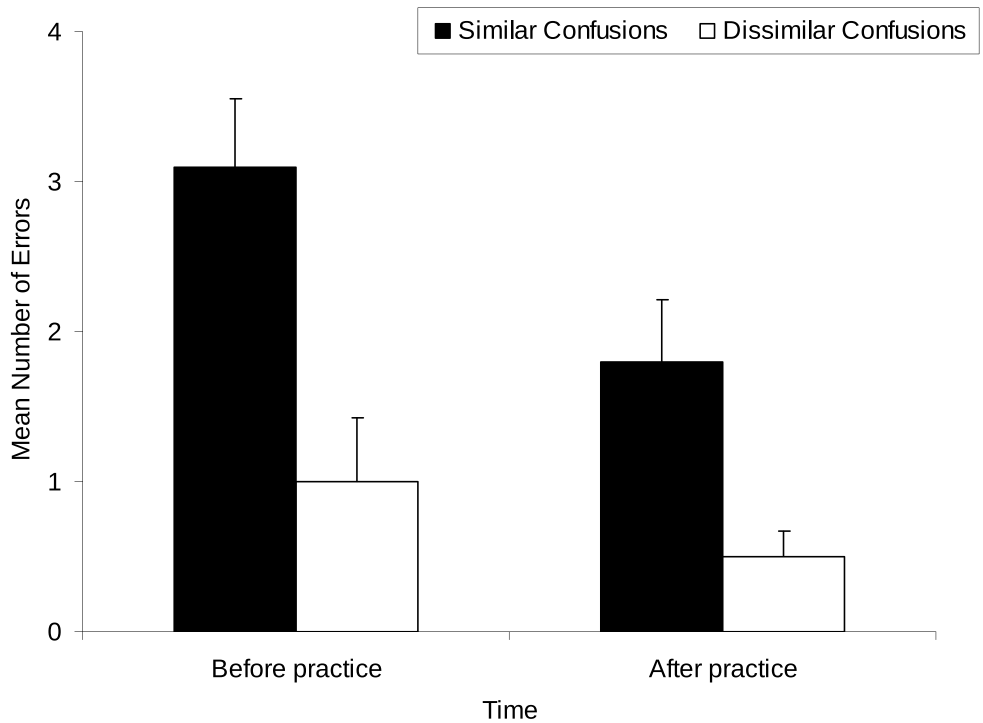

Figure 11. Mean number of actions with cylinder errors with to type of confusion as a function of time.

0.63). There was also a main effect of semantic similarity; F (1,9) = 17.225, p = 0.002. Participants made more action errors for similar confusions (mean = 2.45, SD = 1.24) than dissimilar confusions (mean = 0.75, SD = 0.76). However, there was no interaction between time and semantic similarity; F (1,9) = 1.161, p = 0.309. Finally, the task of actions with the novel objects was analyzed (Figure 12). Again, the analysis revealed a main effect of time; F (1,9) = 12.531, p = 0.006. Participants produced more action errors before practice (mean = 3.7, SD = 2.57) than after practice (mean = 0.8, SD = 0.42). There was a main effect of semantic similarity; F (1,9) = 11.592, p = 0.008. Participants made more action errors for similar confusions (mean = 3.6, SD = 2.44) than dissimilar confusions (mean = 0.9, SD = 0.81). However, there was an interaction between time and semantic similarity; F (1,9) = 19.354, p = 0.002. When participants produced actions before practice, they made more similar confusions (mean = 6.2, SD = 4.42) than dissimilar confusions (mean = 1.2, SD = 1.40); t (9) = 3.899, p = 0.002. However, when participants produced actions after practice, they made equivalent number of errors for similar confusions (mean = 1.0, SD = 0.82) and dissimilar confusions (mean = 0.6, SD = 0.70); t (9) = 1.0, p = 0.172.

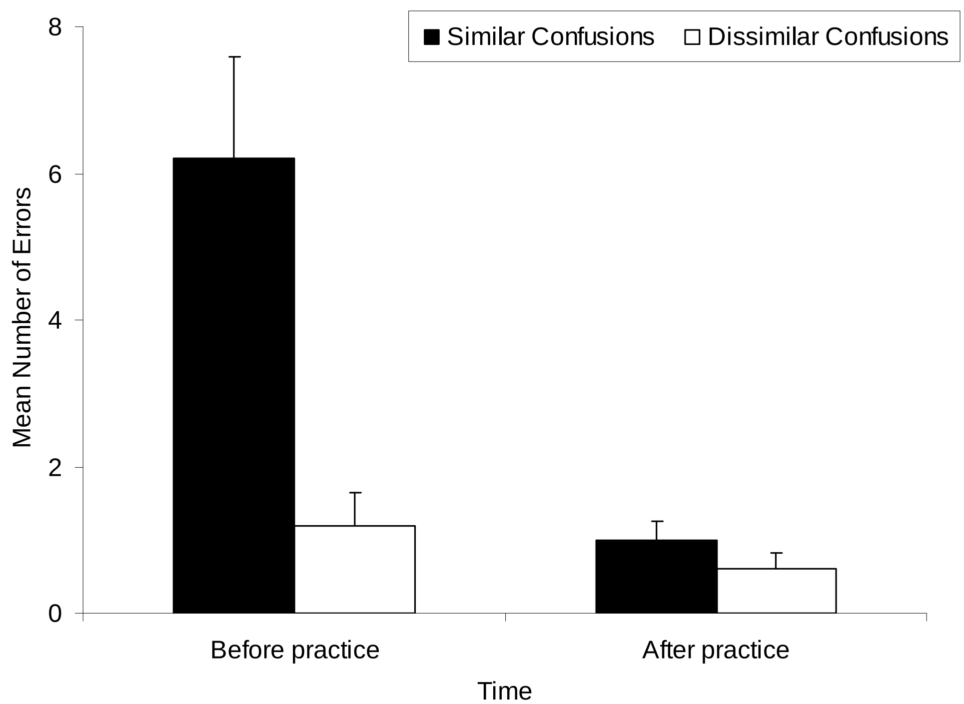

Figure 12. Mean number of actions with novel objects errors to type of confusion as a function of time.