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We hereby approve the Dissertation

of

Lin Ye

Candidate for the Degree:

Doctor of Philosophy

____
Director
Dr. Leonard S. Mark

____
Reader
Dr. Robin D. Thomas

____
Reader
Dr. Joseph G. Johnson

____
Reader
Dr. Leonard J. Smart

____
Graduate School Representative
Dr. Aimin Wang

ABSTRACT

PLACING OBJECTS IN THE CONTEXT OF GOAL-DIRECTED ACTIONS: CULTURAL DIFFERENCES BETWEEN CHINESE AND AMERICAN STUDENTS IN THE PERCEPTION OF MULTIPLE AFFORDANCES FOR OBJECTS

by Lin Ye

Ye et al. (2009) showed that the perception of one affordance of an artifact can decrease the likelihood of detecting a second affordance when neither affordance supports the function for which the object was designed. The current study examined the proposal that experience using tools and artifacts designed to perform multiple functions might play a role in that finding. In Experiment 1, American and Chinese students at Miami University were presented with collections of artifacts, such that one-third had only the affordance 1 (e.g., scoop-with), another third had only affordance 2 (e.g., pierce-with) and the remaining objects had both affordances. Neither affordance was the one for which the artifacts had been designed. Tasks 1 and 2 required participants to judge which objects had affordances 1 and 2, respectively. The results showed the perception of first affordance decreased the likelihood of identifying the second affordance for objects with both affordances, though the magnitude of the difference was significantly larger for the American students. This difference between the two groups of students disappeared when the task required students to use the objects to perform a goal-directed activity (Experiments 2 and 3). When the same grip was used for both actions, both Chinese and American students were likely to spontaneously use the object for both tasks. But when a different grip would be used, participants were far more likely to miss the second affordance of the object. These findings suggest that the perception of a complex affordance entails the perception of the nesting of affordances for component actions, such as how an object can be reached for, grasped (grip and location of hand placement) and wielded. These results are discussed with respect to the embodiment of perception as situated in the actor's goal directed activities and the involvement of the dorsal and ventral streams in the visual system.

PLACING OBJECTS IN THE CONTEXT OF GOAL-DIRECTED ACTIONS: CULTURAL DIFFERENCES BETWEEN CHINESE AND AMERICAN STUDENTS IN THE PERCEPTION OF MULTIPLE AFFORDANCES FOR OBJECTS

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Lin Ye

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INTRODUCTION

Gibson (1979) introduced the concept of an *affordance* to refer to the functional utility of the layout of surfaces taken with reference to prospective actors and their capabilities. To perceive an affordance for an object is to perceive this relation between relevant object properties and the capabilities of the actor (Stoffregen, 2000). Dennett (1987) observed that most man-made objects are designed to be used for a specific purpose. Designers construct affordances for the objects they plan in order to support specific goal-directed actions for users. A hammer is designed to be grasped and wielded so enable the user to pound nails into a hard substance. A chair affords sitting on. Affordances embody potential actions for tools and artifacts. From a design perspective, the challenge is to create affordances that are required to support a particular activity (Gibson, 1979; Torenvliet, 2003). A well-designed artifact will also provide information about the affordances for prospective users (Gibson, 1979; Norman, 2002), thereby facilitating recognition of the use for the artifact. Toward this end it is important to distinguish among (a) *the affordance* which exists regardless of whether it is detected, (b) *the available information for the affordance* and (c) *the act of picking up information for the affordance*, i.e., perception of the affordance.

While the designer's intention is for the artifact to be used to support a *particular* goal-directed activity, artifacts typically afford possibilities for action other than the one intended by the designer. This was shown in the 1980 film (released by CAT Films) *The Gods Must Be Crazy*. Bushmen living in the Kalahari Desert encountered a Coke bottle, their first contact with the products of modern technology. This bizarre object suddenly changed their lives. Women used the bottle to wash laundry and crush fruit; men used it to dig for food in the earth and polish animal skins; for children the Coke bottle was a toy, it became a musical instrument. The Bushmen discovered various uses for this novel object, a vivid demonstration that objects, especially human artifacts, typically afford more than one action. In our everyday lives people often accomplish a task in the absence of an object designed for that purpose; people often find another object that affords the desired goal-directed activity. This entails using an object for a purpose not intended by the designer, in effect exploiting affordances that exist, though were not part of the designer's original plan for how the artifact should be used. For example, when we are looking for something to sit on when a chair in not available, a box made of wood with a large, flat surface that is sufficiently sturdy to support the actor's weight could be used to sit on. Dental floss can function as thread with which to sew on a button, hold eyeglasses together, or cut wedding cake (it really works well).People commonly use a coffee mug to hold pens or as an ashtray. A hammer might serve as a paper weight or as a door jam to prevent a door from closing. Thus, under some circumstances people are able to recognize that objects afford actions for which they had not originally been designed.

In many parts of the world, artifacts are intended (and used) to serve multiple functions. The Chinese people use chopsticks as stirrers, corn holders, hair clips, and eating utensils. When the ideal artifact for performing a specific action is not available, people often find objects with the needed affordance as a substitute. This investigation examines the problem of how a prospective actor is able to detect a particular affordance of an object from the many affordances that are available. Our strategy is to focus on how the perception of one of object's affordances affects the likelihood that the same perceiver will notice a different affordance shortly thereafter. For clarity, we refer to an artifact's designed function as its *primary* or d*esigned* affordance and other functions for which the object could be used as *secondary* or *nondesigned* affordances.

The Perception of Multiple Affordances for an Object

From Gibson's (1979) ecological perspective, artifacts typically afford more than one action and there is information for those affordances available to a prospective actor. In light of the availability of information for affordances of an object, it is somewhat surprising (from this perspective) that people sometimes have difficulty detecting (perceiving) these nondesigned uses for an object.

Functional fixedness. The phenomenon of *functional fixededness* (Maier, 1930; 1931) shows that people sometimes fail to notice an unconventional use for an object because of their familiarity with the function for which the object was designed. People may have difficulty noticing secondary affordances of an object when the task entails functions that are different from those related to the use for which the object was designed. Functional fixedness has been observed in other cultures, including a "technologically sparse" culture in which people had little experience with the intended function of specific artifacts (German & Barrett, 2005). When the designed function was primed, participants reacted more slowly to atypical functions for that object than did members of a control group. As in earlier studies, people initially focused on a specific function of an object, which hindered their abilities to detect other uses. The strong association between the physical properties of an object and its typical use seemed to impede a prospective actor from discovering novel uses for the object, especially when the novel use entails exploiting affordances that were not part of the designer's original plan for how the artifact should be used.

The earliest explanations of functional fixedness suggested the prospective actor *fixates* on an object's the most common function, which *blocks* (Duncker, 1945) or *blinds* (Luchins, 1945) people from detecting other potential uses for the object. That is, the perceivers' knowledge of the primary function of an object inhibits their ability to detect another function of that object. Since that time the treatment of functional fixedness has been largely descriptive employing constructs such as *fixation*, *blocking*, *failure of retrieval* and *insight* (e.g., Dominowski & Dallob, 1995). Because these constructs are introduced *post hoc*, they offer little explanatory power and raise questions about why such interference should be encountered in the perception of multiple uses for an object. Those same constructs become obstacles when trying to understand what enables someone to detect a secondary affordance for an object, that is, to break functional fixedness.

Neisser's selective looking paradigm. From an ecological perspective, the puzzle of functional fixedness centers around the availability of information for multiple uses for an object: Why does the prospective actor fail to detect the information for additional affordances? For James and Eleanor Gibson, the pickup of information for affordances is grounded in the exploratory activities of the prospective actor (Gibson, 1988; Gibson, 1979; also Mark, Balliett, Douglas, Craver, Douglas, & Fox, 1990; Mark, Jiang, King, & Paasche, 1999; Neisser, 1976). Detecting a secondary affordance for an object may involve having to initiate different exploratory activities, similar to what Neisser (1976) referred to changing *perceptual cycles*. The association between certain physical properties of an object and its designed use may entail different exploratory actions than those required to detect information for a novel use for the object, especially when the nondesigned use entails a different way of grasping and wielding the object.

The challenge inherent to detecting multiple affordances for an object is somewhat similar to the selective looking task developed by Ulric Neisser and his colleagues (Bahrick, Walker, & Neisser, 1981; Becklen & Cervone, 1983; Littman & Becklen, 1976; Neisser, 1979; Neisser & Becklen, 1975). In the selective looking task, films of two events were artificially superimposed upon one another such that observers saw two groups of three actors passing a ball around. By having observers count the number of passes among actors wearing the light colored shirts, Neisser and Becklen (1975) demonstrated that observers could selectively attend to one of the spatially superimposed events. Bahrick et al. (1981) reported that infants as young as 4-months were similarly able to selectively attend to one of the events. An often copied extension of the original selective attention study introduced an unexpected event, a women carrying an umbrella walking through the people passing the ball around (Neisser & Becklen, 1975; also Becklen & Cervone, 1983; Littman & Becklen, 1975). Only about 20% of the observers who were engaged in the selective looking task noticed this odd event; in contrast, the woman was spontaneously reported by most observers not engaged in the selective looking task. Becklen and Cervone also reported that with practice in the selective looking task, observers were more likely to detect the unusual event.

Neisser's selective looking task *spatially* and *temporally* superimposed two events in order to examine the inherent selectivity in the act of perception. The perception of multiple affordances for an object creates a naturally-occurring *spatial* analog of the selective looking task in which observers have to ascertain the possibilities for interacting with the object in performing a goal-directed activity. For a prospective actor, each affordance entails a manner of *gripping* (i.e., the number of fingers in contact with the object as well as the placement of the fingers) and *wielding* the object to achieve the intended goal. Under what conditions are prospective actors able to switch from perceiving one of an object's affordances to another?

Ye, Cardwell, and Mark (2009) began to address this question by developing a paradigm to observe how identifying one nondesigned use for an object could interfere with identifying a second nondesigned use for the same object. Ye et al. presented

American college students with a collection of nine objects. Three of the objects afforded only one action (e.g., scoop sand); three of the objects afforded only a second action (e.g., pierce a plastic bag), but not the first; and the remaining objects afforded both actions(e.g., scoop & pierce). Observers' first task was to identify all of the objects that afforded *scooping sand with*. This would include both objects that afford scooping sand, but not piercing a bag, and objects that afford both actions. Task 2 involved identifying objects that afforded *piercing a hole in a plastic bag*, which included both objects that only afforded piercing, but not scooping and objects that afforded both piercing and scooping. The key finding was that on Task 2, participants were more likely to identify objects with only the second affordance than objects that afforded both actions that they had previously identified as supporting the first action. Ye et al.'s findings showed that identifying one nondesigned affordance for an object decreased the likelihood of noticing a second nondesigned affordance for that object. Ye et al.'s findings showed that functional fixedness may also apply to the objects' non-designed uses. That is, once a nondesigned function for an object is perceived, it becomes more difficult to notice a second nondesigned function for an object.

Ye et al. (2009, Experiment 2) were also able to demonstrate that on Task 2, objects with only the second affordance were not simply better instances of that second affordance than objects with both affordances. A third experiment also showed that the basic pattern of results reported in their first experiment were specific to judgments of the uses for objects and did not apply to judgments for simple physical properties, such as color and shape.

The current study examines two problems posed by the results of Ye et al.'s (2009) findings. Experiment 1 considers the possibility that the failure to notice a second function for some objects may reflect subjects' experiences in using objects to perform multiple functions. In western culture, tools and artifacts are typically used to perform a particular function. Would the same pattern of results obtain for people from East Asian cultures in which artifacts are frequently used to perform multiple functions? Experiments 2 and 3 attempt to provide an explanation for why on Task 2 Ye et al.'s observers were able to identify the second function of objects with both affordances on some occasions, but not others. Although they identified more objects with only the second affordance (mean = 89%) than objects with both affordances for which they had previously identified as having the first affordance (mean = 58%), it is still the case that they noticed the second affordance for a significant number of objects with both affordances. An adequate explanation of Ye et al.'s findings should be able to distinguish conditions under which the second affordance is noticed from those conditions where observers failed to notice that affordance.

The Role of Culture

To what extent might Ye et al.'s (2009) findings be a product of western culture? In western culture there is a strong tendency to use tools that are designed to perform a particular function. American consumers tend to own numerous special-purpose tools (e.g., cooking utensils) whose designs are often optimized for performing specific functions. In this regard, Asian and western cultures differ in the types of tools that are used in activities of everyday living, such as cooking. In many parts of the world, artifacts are intended (and used) to serve multiple functions. As an illustration, the Chinese people use chop sticks to perform a variety of different functions—as stirrers, corn holders, hair clips as well as eating utensils. While chop sticks may not be the optimal tool to perform each of these functions, they possess properties necessary to support a number of goal-directed activities, thereby reducing the number of tools the Chinese people use to perform commonplace activities. Given the multiple functions often afforded by the tools used in Asian cultures, might people from these cultures be able to more readily detect multiple uses for a given object than Americans?

Sociocultural influences on perception. Vygotsky (1962) also attempts to understand the influence of sociocultural context as well as the physical environment on people's behavior. Nisbett (2003; also Nisbett, Peng, Choi, & Norenzayan, 2001) argued that people from different cultures focus on different aspects of the environment. East Asians who live in collective society perceive themselves embedded in a whole context and are expected to be interdependent and, consequently, pay attention to others for maintaining a harmonious relationship with people of various status levels. The habit of attending to the relationship in social world would prompt East Asians' attention to the relationships among objects and the contexts. In contrast, western culture emphasizes the autonomy of individuals whose concerns are more focused on themselves and their immediate family members. Westerners would focus on the object and individuals' goals. As a consequence, people from different cultures may pay attention to different information in the environment. People from Asian cultures tend to be more sensitive to the functional relationships among classes of objects and their relationship in the environment, rather than structural relationships to which Americans are more attuned (Nisbett, 2003; Ji, Peng, & Nisbett, 2000; Masuda, & Nisbett, 2001; Miyamoto, Nisbett, & Masuda, 2006). When shown a target picture and asked to choose a second picture that is more similar to the target picture, American subjects typically based their choice on structural/taxonomic similarities among objects in the pictures. In contrast, Asian subjects based their similarity judgments on functional relationships between objects in the pictures. For example, given a target picture of a cow, Americans were more likely to choose a picture of a chicken (taxonomic relation, both are animals) as more similar to the target, while Asians were more likely to choose a picture of grass (functional relation for cow eating the grass). This cultural difference was even observed in young children (Chiu, 1972). Given a triplet *man-woman-child*, Chinese children grouped two pictures based on relation, such as "the mother takes care of baby". In contrast, American children preferred to group two pictures taxonomically, that is, "the man and woman are both adults". Also, Asian people appear to be more field-dependent, focusing the relations among objects and events in the world and perception of object influenced by the background or environment, while people from western cultures tend to be more field-independent (Witkin & Berry, 1975) in their cognitive style. Masuda and Nisbett (2006) found that Asians directed their attention more to context information and objects changes than American participants. They showed American and Japanese participants pairs of video scenery clips in a certain sequence. For each pair of images, there were some changes between two pictures, either in focal object (e.g. missed one wheel in the car) or context information (location of the clouds). Participants were asked to press a key to indicate a detection of changes. The results indicated that Japanese participants responded to changes in contextual information faster and detected far more context changes than Americans. American participants detected more object changes than Japanese participants. This implies that East Asians allocated their attention more to the peripheral and background information than did the Americans (Masuda et al., 2008; Chua, Boland & Nisbett, 2005).

The role of language in perception across cultures. Vygotsky (1962) also views language as playing an important role in shaping people's cognition. Tardif, Shatz, and Naigles (1997) found that the Chinese language emphasizes action information by showing that Chinese mothers spontaneously produced more verbs than American mothers during maternal interactions with their children. Compared with American mothers, Chinese mothers referred to the relationship between their babies and themselves and the environment when mothers were talking and playing with their infants. Tardif (1996) also observed that as early as 22 months of age, Chinese children produced more verbs or action words than nouns or object labels; the opposite pattern was observed in American children. The emphasis on action information in the Chinese language may also be illustrated with analyses of *classifiers* (Chao, 1968). Classifiers are always used after measure words (numbers), which denote the quantity of objects. The classifier follows the measure word to indicate objects' physical properties such as shape, size, length as well as the action-related conceptual properties, such as *graspability*. By knowing the classifier the listener learns something important about the object.   The classifiers direct native Chinese speakers/hearers to look for certain information, pay attention to environment properties and (potentially) execute certain actions. For example, "one knife" in Chinese with the classifier would be "*yi*[1] –*ba*[1]-*dao*[1]", where *yi*[1] means one, *dao*[1] means knife, and the classifier *ba* [3rd tone], which is used to classify graspable objects, will lead a speaker of Chinese to pay attention to graspable aspect properties, such as a long handle (a key, knife, or shovel). The classifier *zhang* [1st tone] denotes a flat surface. The classifier *ping* [2nd tone] denotes a covered container that can hold liquid. Schmitt and Zhang (1998) reported that the classifiers in the Chinese language affect a Chinese speaker/hearer's expectation about the object referred to by the classifier and may affect their decisions making in purchases. When one product is out of stock, people would more likely select as an alternative a product that shares the same classifier. For example, if "one *liang*[4] motorcycle" is not available, consumer would more likely to buy "one *liang*[4] bicycle". Classifier of "liang[4]" is used for transportation tool such as bicycle, motorcycle, stroller, car etc. Because of this property of the Chinese language, Chinese people might be more likely to notice the possibilities for actions associated with objects. However, it is not clear whether the use of classifiers would prompt Chinese people to notice multiple uses for objects simply because the classifier calls attention to a particular property. If the second use for the object entails that property, then the use of classifier may increase the likelihood of noticing the second function for the object. However, if the second function does not involve that property, then the classifier might distract the person from noticing the second function, thereby creating a kind of functional fixedness.

To summarize, there is some reason to suppose that cultural and linguistic differences between Asians and Americans could make Chinese people more likely to notice multiple uses for objects than Americans. Experiment 1 examines this possibility using the basic paradigm established by Ye et al. (2009, Experiment 1). Participants were presented with a collection of objects that could be divided into three classes defined with respect to a pair of affordances. Some of the objects ($O_{AFF\ 1}$) had only the first affordance (e.g., pour-in-able), but not the second affordance (e.g., stretchable). Other objects ($O_{AFF\ 2}$) had only the second affordance, but not the first. The third class of objects ($O_{AFF\ 1\&2}$) had both affordances**.** [The notation. $O_{AFF\ 1}$ should be read, "objects with only the first affordance;" $O_{AFF\ 2}$ should be read, "objects with only the second affordance;" $O_{AFF\ 1\&2}$ should be read, "objects with both the first and second affordances."] Neither of these affordances was the primary affordance for which the objects had been designed. Each participant performed two tasks: For Task 1, participants identified all of the objects with the first affordance. This would include objects with both affordances ($O_{AFF\ 1\&2}$) as well as objects with only the first affordance ($O_{AFF\ 1}$). Immediately after completing the first task, participants performed Task 2 in which they identified objects with the second affordance, which included objects with both affordances ($O_{AFF\ 1\&2}$) as well as objects with only that second affordance ($O_{AFF\ 2}$). If the perception of one of an object's affordances affects whether a person will notice another of its affordances, on Task 2 participants should be more likely to identify objects with only the second affordance ($O_{AFF\ 2}$) than objects with both affordances ($O_{AFF\ 1\&2}$), a finding that Ye et al. (2009, Expt 1) obtained for three of the four pairs of affordances studied.

Experiment 1 replicates this experiment using both native Chinese and American students at Miami University. Would the Chinese students show the same preference for $O_{AFF\ 2}$ over $O_{AFF\ 1\&2}$ on Task 2 as American students had shown in previous work? If the Chinese students are accustomed to paying attention to relational information because many of the objects with which they interact are used to perform multiple functions, then we would expect they will have less difficulty than American students in identifying a second potential function of an object for which they had already identified another use. That is, on Task 2 the Chinese students should identify a larger percentage of $O_{AFF1\&2}$ than the American students. Experiment 1 examined this possibility by replicating our previous study with both American and Chinese students who had come to Miami University for their education.

EXPERIMENT 1

Method

Participants. Twenty American Miami University students participated in this experiment to meet a course requirement. All of these American students were under 20 years of age. Twenty Miami students from China participated in the experiment as volunteers. They consisted of 16 graduate students and 4 undergraduates (age range: 18-28 years, *M* =24). All of the Chinese participants were born in China and had lived in the United States for an average of 21 months (range 6-72 months). The Chinese participants were bilingual and fluent in English, having studied English for an average of 13 years. In this group of 20 students, only 7 had taken a course in English (other than an English class) prior to coming to Miami University.

Materials. The stimuli were same as in previous work (Ye et al, 2009, Expt. 1). Four pairs of affordances were used: (1) *scoop-with / pierce-with*; (2) *pack-with / play-catch-with*; (3) *mop-up-with / floatable*; (4) *pour-in-able / stretchable*. For three pairs of affordances nine objects were placed on a tray, in which there were three objects with the first affordance, but not the second affordance ($O_{AFF\ 1}$); there were also three objects with only the second affordance, but not the first affordance ($O_{AFF\ 2}$) and the other three objects that had both affordances ($O_{AFF\ 1\&2}$). For the affordance pair of *mop-up-with* and *floatable,* the tray contained only six objects, with two objects in each of the three categories. Table 1 lists the objects associated with each affordance category. Appendix 1 (reproduced from Ye et al., 2009) provides a summary of the procedures used to determine the affordance category for each of the objects used.

Design and Procedure. This study used the same method employed by Ye et al. (2009, Expt 1). Participants were presented with a collection of objects that could be divided into three classes defined with respect to a pair of affordances. Some of the objects ($O_{AFF\ 1}$) had only the first affordance (e.g., pour-in-able), but not the second affordance (e.g., stretchable). Other objects ($O_{AFF\ 2}$) had only the second affordance, but not the first. The third class of objects ($O_{AFF\ 1,2}$) had both affordances. [Neither of these affordances was the primary affordance for which the objects had been designed.] Each participant performed two tasks: For Task 1, participants identified all of the objects with the first affordance. This would include objects with both affordances ($O_{AFF\ 1\&2}$) as well as objects with only the first affordance ($O_{AFF\ 1}$). Immediately after completing the first task, participants performed Task 2 in which they identified objects with the second affordance, which included objects with both affordances ($O_{AFF\ 1\&2}$) as well as objects with only that second affordance ($O_{AFF\ 2}$). If the perception of one of an object's affordances affects whether a person will notice another of its affordances, on Task 2 participants should be more likely to identify objects with only the second affordance ($O_{AFF\ 2}$) than objects with both affordances ($O_{AFF\ 1\&2}$).

A tray of objects with one of the pairs of affordances was placed on a table; a random number was attached to each object so that participants would identify objects by the number, rather than by its name.

All participants were tested individually using the same stimuli and procedures. Each participant performed two search tasks in which he/she had to identify objects on the tray that could be used to perform two specific goal-directed actions. For Task 1, participants were instructed to identify all of the objects with one of the affordances in each pair (e.g., scoop-with). When participants indicated that they understood the action being described, they walked over to the tray of objects and identified the appropriate objects by calling out a number attached to the object. After completing task 1, participants were asked to turn their back to the table while a second experimenter re-randomized the locations of objects on the tray. The procedure was then repeated for

Task 2, in which participants identified the objects with the second affordance of that affordance pair (e.g. pierce–with). For each task the order in which the objects that supported that action was recorded.

All participants judged each of the four pairs of affordances. For each pair of affordances, half of the participants identified objects with affordance A (Task 1) and then affordance B (Task 2). The remaining participants judged the affordances in the reverse order. The order in which participants judged the four trays was counterbalanced such that each tray was presented in each ordinal position an equal number of times across the 20 participants from each country.

Instructions. Chinese participants were given the same instructions in *Chinese*[1] by a bilingual Chinese experimenter. The verbatim instructions are provided below in italics.

I am going to show you a tray of objects. I want you to identify each of the objects that have the following property: The property is then described from one of the following (below) pairs of actions.

If necessary you may pick up any of the objects. You should identify each object on the tray that has this property by calling out the number that is attached to the object. Only list objects that you are confident have the property. This means that if you are unsure whether the object has this property, you should not identify it.

<u>*Scoop-with / Pierce-with*</u>

Scoop-with: An object that you could use to scoop sand out of this plastic bag (prop) if the bag was torn open.

Pierce-with: An object that you could use to poke a hole or tear this plastic bag (prop) filled with sand.

<u>*Pack-with / Play-catch-with*</u>

Pack - with: An object that you could use as packing material so that you could pack an egg in this box (a prop) so that it won't break. You may assume that you have many of each of these objects so that you can fill the box with the object you have chosen.

Play-catch - with: An object that you could use to play catch with someone who is standing on the other side of this room (the distance is about 20 feet).

<u>*Mop-up / Floatable*</u>

Mop-up: An object that you can use to help mop up a glass of water that spilled on a table.

Floatable: An object that you could put into a bathtub full of water and it would not sink into water.

Pour-in-able / Stretchable

Pour-in-able: A container or enclose space into which you can pour a small amount of water so that the water would not leak out.

Stretchable: An object that you can stretch by holding it in your hands and stretching it so that it is noticeably different in length without breaking or tearing the material.

After completing Task 1, the second action in the pair was described and Task 2 was performed. This procedure was repeated for each pair of actions.

The instructions in Chinese were constructed by translating the above directions into Chinese by a native Chinese speaker and then back translated into English.

Results & Discussion

In order to determine whether the perception of the one affordance of an object (performance *in Task 1*) affects the likelihood of detecting another affordance for that object (performance *in Task 2*), our data analysis focused primarily on Task 2. The dependent variable was the percentage of the objects identified on Task 2.

Analysis of Task 1. To calculate the percentage of $O_{AFF\ 2}$ and $O_{AFF\ 1\&2}$, we first had to examine participants' responses on Task 1. Although we had determined in advance which objects actually had both affordances (Appendix A), we were interested in those objects for which both affordances were actually identified. If the first affordance of an object was not detected (i.e., the participant did not identify the object as having the first affordance), then there would be no basis for arguing that the detection of the first affordance in some way affected the detection of the second affordance for that object. Any object with both affordances for which participants had not identified as having the first affordances in Task 1 was treated as having only the second affordance for that participant in Task 2, i.e., as an $O_{AFF\ 2}$. This would ensure that a participant had actually perceived objects with both affordances as having the first affordance on Task 1, which could then affect the detection of the second affordance on Task 2. For this reason, we present the results of Task 1 in Table 2 in order to show the percentage of objects with both affordances that were not perceived as having the first affordance and thus was treated as having only the second affordance.

Table 2 shows the percentages of objects with only the first affordance and objects with both affordances that were identified as having the first affordance in Task 1. For *pour-in-able/stretchable* affordance pairs, the percentage of identified objects having only the affordance of *pour-in-able* was comparative to the percentage of objects with both affordances. For the remaining three affordances, roughly a third of all objects with both affordances was missed as instances of the first affordance on Task 1, and thus was treated as objects with only the second affordance on Task 2.

A three-way, repeated measures ANOVA analysis was conducted with two within-subject factors (object type and affordance pair) and one between-subject factor (nationality). There were main effects of affordance pairs, F (3, 36) = 11.09, $p < .0001$, power = .999, and object type, $F(1, 38) = 109.48$, $p < .0001$. Power =.966. There was also a significant interaction of affordance pairs and object type (F (3, 36) = 7.41, $p < .001$, power = .974). The three way interaction among affordance pair, object type, and nationality was not significant, (F (3, 36) = .65, p =.59, power = .17), nor were the interactions of affordance pair and nationality (F (3, 36) = .38, p =.77, power = .12), and object type and nationality, F (1, 38) = .45, p =.51, power = .1

There was no difference between the Chinese students and American students on the percentage of identified objects in Task 1. The Chinese and the American students identified the same percentage of object with both affordances ($O_{AFF\ 1\&2}$) : M = 77% ; for the object with only one affordance ($O_{AFF\ 1}$), Chinese detected 92% and American identified 88% of $O_{AFF\ 1.}$ This indicates that there were no meaningful differences between the Chinese and American students on Task 1.

Task 2. The dependent measures were the percentages of $O_{AFF\ 2}$ and $O_{AFF\ 1\&2}$ identified on Task 2. Figure 1 depicts the mean percentages of $O_{AFF\ 2}$ and $O_{AFF\ 1\&2}$ for the Chinese and American students summed across the four pairs of affordances. This figure shows that both groups of students identified similar percentages of $O_{AFF\ 2}$. However, the two groups differed with respect to the percentage of $O_{AFF1\&\ 2}$ identified. Although both groups identified a larger percentage of $O_{AFF\ 2}$ than and $O_{AFF\ 1\&2,}$ Figure 1 shows that the magnitude of the difference between $O_{AFF\ 2}$ and $O_{AFF\ 1\&2}$ was significantly larger for the American students.

A three-way repeated measures ANOVA was conducted with two within-subject factors (2 object types and 4 affordance pairs) and one between-subject factor (2 levels of Nationality). There were significant main effects of affordance pairs (F (3, 29) = 11.09, p < .0001. power = .998) and object type (F (1, 31) = 109.48, p < .0001. power =1). Also, there were a significant interactions of object type and nationality (F (1, 31) = 31.13, p < .0001, power = 1) and affordance pairs and object type (F (3, 29) = 11.14, p < .0001, power = .998). There was no interaction of affordance pair and nationality, F (3, 29) = .67, p =.54, power = .19, nor did the three-way interaction among affordance pair, object type, and nationality reach the .05 level of significance, F (3, 29) = .45, p =.72, power = .13.

The follow-up pairwise comparisons indicated that there was no difference between Chinese (M= 94.43) and American (M= 90.91) students on the percentage of objects with only the second affordance ($O_{AFF\ 2}$), p =.37. However, the Chinese students (M = 79.25) identified far more objects with both affordances ($O_{AFF\ 1\&2}$) than the American students (M = 41.03), p *<.0001.*

Figures 2 and 3 show these data for each of the affordance pairs for the $O_{AFF\ 1\&2}$ and $O_{AFF\ 2}$ respectively. Figure 2 indicates that the Chinese students identified more $O_{AFF\ 1\&2}$ than the American students. However, Figure 3 indicates that both groups identified comparable levels of $O_{AFF\ 2}$. In looking at the data for the American students, it is evident that the basic pattern of results reported by Ye et al. (2009, Expt. 1) was replicated in this experiment, though the magnitude of the difference between the $O_{AFF\ 1\&2}$ and $O_{AFF\ 2}$ objects was somewhat larger.

The outcome of this study showed clear differences in perceptual judgments between Chinese students and their American counterparts in regard to their ability to detect multiple uses for a single object. On Task 2 the Chinese students were far more likely to identify objects with both affordances as having the second affordance than the American students. This suggests that the Chinese students may be more adept at identifying more than one function for an object. However, it is unclear what might be responsible for the observed difference between the American and Chinese students.

Future research might consider several possibilities derived from previous cross cultural research, sociocultural and linguistic differences as well as the effect of practice. These three possibilities are not mutually exclusive. Earlier we reviewed research that points to the impact of sociocultural differences on cognitive style and perceptual attunement to different aspects of the environment (Masuda & Nisbett (2006). People from East Asian cultures focused on functional relationships among the various parts of the environment, whereas people from western cultures tended to focus on structural/taxonomic relationships. In the perceptual judgment tasks used in Experiment 1, there was information available for both affordances. The results indicate that Chinese students were more likely than the American students to pick up the information for both affordances. The sociocultural environment in which the Chinese students grew up may have encouraged them to pay attention to the functional relationships required in these tasks. In doing so, this may have facilitated the pickup of information for the second affordance. It also could be the case that the Chinese students simply have more experience in using objects for more than one purpose. As mentioned earlier, Chinese tools are often designed and used to perform multiple functions. Thus, the larger percentage of $O_{AFF\ 1\&2}$ identified might be a product of experience in using the same object for different tasks. In addition, these results could also have been partly due to characteristics of the Chinese language, aspects of which focus the speaker/hearer's attention on action information embodied the functional relations between objects and environment. As a consequence, they may be able to easily detect information for an affordance than American students. Finally, the nature of the judgment task may have contributed to the differences between the Chinese and American students. In this experiment participants made judgments about the possibility of using an object to perform a task; they did not manipulate the objects or attempt to perform a goal-directed task. It is possible that the differences in the judgments of the two groups of students were a product of the criterion that they used in judging how effectively an object could be used to perform the implied action. Experiment 2 establishes a methodology by which participants can interact with objects and attempt to use them to perform specific goal-direct tasks.

Although Experiment 1 provides some evidence for differences between Chinese and American students, the results also show that on Task 2 the Chinese students identified somewhat fewer $O_{AFF\ 1,2}$ than $O_{AFF\ 2}$. Thus, the fundamental pattern of results reported by Ye et al. (2009) did obtain in this experiment. As in Neisser's selective looking experiments, both groups of observers could attend to one of the object's affordances; difficulties arose when a second affordance had to be detected (Task 2). It seems that when observers were asked to look for a second affordance, they were not as readily able to switch their attention in order to detect the second affordance as Neisser's subjects, though they were able to do so on more than half of the occasions in which they were required to do so. Experiment 2 attempts to develop a methodology to examine this puzzle.

EXPERIMENT 2

The results of Experiment 1, as well our previous work (Ye et al., 2009, Experiment 1) pose a curious challenge. Among American students participating in the experiment, there was a clear tendency on the second task to identify the objects with only the second affordance ($O_{AFF\ 2}$) more often than objects with both affordances ($O_{AFF\ 1\&2}$). While this difference was statistically significant beyond the 0.05 level, it is also the case when someone identified one of an object's affordances, quite often that observer could also identify the second affordance for that object, though not as often as with objects with only the second affordance. Thus, an explanation of the outcome of earlier studies should provide some understanding about why it is that sometimes people can readily identify the second affordance in an object and on other occasions they apparently fail to notice the second affordance for that object.

Toward this aim, it is important to keep in mind that a complex, goal-directed action entails detecting and acting upon a nesting of affordances. Embedded within the affordance for a complex goal-directed action is a set of simple affordances that support specific actions comprising the activities leading to realizing the goal. Consider the complex, goal-directed activity of digging a small hole in sand to bury an object: For an object to afford digging with in the sand, it has to be graspable on a part of the object that allows the "scooper" part of the object to be appropriately oriented relative to the part of the environment being operated upon. The object will then have to be wielded in a manner that provides the appropriate contact with the environment—in the case of digging, the scooper needs to contact the substance being moved (sand), such that some of the substance remains in the scooper. Additional movements are required to relocate the substance to a new location. The perception of a glass as affording *digging with*, entails perceiving how the glass can be grasped (i.e., grip configuration), as well as the ways the glass can be wielded to achieve the goal of picking up soil and moving it to its new location. That same glass could also be used to perform a very different action, say, crushing a cracker. However, the prospective actor could use the glass to perform that action in two different ways. From our experience, most people crush the cracker by placing the palm of their hand over the mouth of the glass and then pressing the bottom of the glass against the cracker. But a few people will use the same grip as described above for scooping; they will then either wield the glass so as crush the cracker either by pressing the bottom of the glass against the cracker or by using the edge of the bottom to pound the cracker. The point is that the acts of scooping and pounding entail at least two component actions: grasping and wielding.

Returning to the problem of understanding why sometimes people notice a second function for an object and on other occasions they do not, Experiment 2 examines the following possibility: The likelihood of noticing a second function for an object increases when the component actions, in particular the grip configuration used, for the second function are similar to those component functions used to realize a previously noticed function. When an object is grasped and wielded in the same way to perform two different functions, people will be more likely to notice the second function than when the component actions are very different, that is, the object would be grasped and wielded differently in performing the two actions. The actions entailed in grasping and wielding an object in performing a pair of complex, goal-directed actions are an important determinant of whether the second function for an object is noticed. Experiment 2 examines this hypothesis.

Prediction 1. We predicted that people would use the object with both affordances ($O_{AFF1\&2}$) for both actions if they gripped the object in the same way and would fail to identify the object as supporting the second action in Task 2 if grips were different. Returning to the example of a glass that can be used for scooping sand and pounding a cracker, this proposal predicts that a person will notice that the glass can be used for scooping and crushing if they were to use the same grip for both actions. However, people who use a different grip (e.g., hold the glass by placing the palm of the hand on the mouth of the glass) in order to crush the cracker should be less likely to notice the second function. Thus, the hypothesis predicts circumstances under which some people will notice the second affordances, while other people might not.

Prediction 2. From the perspective of Neisser's selective looking experiments and his concept of a perceptual cycle, we also expected that violations of these predictions would be *less* likely to occur when participants failed to use the $O_{AFF\ 1\&2}$ for the second action, but would have used the same grip. This is because they would not have had to switch perceptual cycles in order to detect the second affordance. In contrast, switching perceptual cycles would be required to occur in order to detect the second affordance for those objects requiring two different grips to perform the two actions; but, if the participant is able to switch perceptual cycles, then the participant should be able to detect information for the second action and thus use the object for both actions. Because it is more difficult to switch perceptual cycles than to maintain the same cycle, we expect that participants should rarely fail to detect the second affordance in objects that would be grasped in the same manner for both actions. To examine these predictions, participants in Experiment 2 were encouraged to pick up and explore the objects used in the experiment. The task used in Experiment 2 required participants to pick up and use the object to perform the desired action.

Method

Participants. Fourteen Miami University undergraduates participated in this experiment for a course requirement. All participants were American students whose first language was English. Due to equipment failure, the data for one participant was discarded.

Materials and goal-directed actions. Two pairs of affordances were used: *Scoop-able-with* vs. *Pound-able-with* and *Dig-with* vs. *Cut-with*. (A procedure nearly identical to the one described in Appendix 1 was used to determine the affordances for the objects that were selected for Experiments 2 and 3.) *Scoop-able-with* was described as something you could use to scoop rice with in order to transfer it to another container. *Pound-able-with* was described as something with which you could use to crush a cracker. For the second pair of affordances, *dig-able-with* was described as something that could be used to dig a hole in a container of soil in order to bury a ping-pong ball. Table 3 provides a list of the objects

Instructions. The following descriptions of each of the actions scenarios were read to participants. The experimenter who read the instructions demonstrates each of the actions following the instructions.

Scoop-with: *Imagine that you are planning to cook a cup of rice. Which object do you think is the most suitable object to scoop a cup of rice with?*

Pound-with*: An object that you can pound with repeatedly with enough force to break this Melba toast. Pounding entails lifting up an object and then lowering it with force in order to break the toast.*

Cut-with*: Imagine that you have some ply-dough and need to cut it into strips. Which object do you think is the most suitable object to cut this play-dough with?*

Dig-with: *Imagine that you are going to dig a hole in sand. The size of the hold should be big enough to bury this ping pong ball.*

*Procedure***.** Participants were tested individually. After informed consent was obtained, the entire session was videotaped so that the hand grip and actions performed with each object could be categorized. For each pair of affordances, participants performed two tasks in which they had to identify objects on the tray that could be used to perform a particular action "in a reasonably efficient way" and then actually perform the action with objects.

After the participant's informed consent was obtained, the first set of objects was uncovered. Prior to presenting participants with information about the task and actions involved, participants were encouraged to pick up the objects and handle them. This was done so that participants could learn about the properties of the objects prior to beginning the experimental tasks.

When participants were finished exploring the objects, the experimenter identified the first goal directed action to be performed. When describing each affordance, one of the experimenters gave a verbal description of the intended action and then demonstrated it by using an object that was not among those used in the experiment. The participant was then instructed to identify an object that he/she was *confident* could be used to perform the intended goal-directed action. After the action using the first object was completed, the participant was instructed to find another object that she/he was *confident* could be used and to perform the action. This procedure was repeated until the participant indicated that none of the remaining objects could be used. A second experimenter recorded which objects were used.

When participant indicated that there was no other objects could be used for the first action, the second action was described and demonstrated. The participant then identified objects that could be used to perform the second action following the same procedure as the first task—identifying an object that could be used and then picking up the object and performing the action. Again, an experimenter noted which objects were used.

When Task 2 was completed participants were asked to perform this second goal-directed action in the Task 3 for those objects that afforded both actions ($O_{AFF\ 1,2}$) that they did not select in Task 2. These objects were, in effect, objects for which participants had *missed* detecting the second affordance.

This entire procedure was then repeated for the second pair of affordances. The order in which participants were given the two pairs of affordances was counterbalanced. Within each pair of affordances, the order in which the affordances were presented was also counterbalanced.

Coding of the grips used in performing the actions. Only the objects with both affordances were coded because we wanted to examine the grips for objects with both affordances. All videotapes were digitized into action clips for each object that participants used for the goal-related actions in Task 1 and Task 2 (or Task 3 if they missed the $O_{AFF\ 1\&2}$ in Task 2). Two experimenters independently compared the action clips for each $O_{AFF\ 1\&2}$ and then categorized the grips. Each grip was categorized using a scheme based on the work of Newell, Scully, Tenenbaum, and Hardiman (1989): two finger-grip (thumb and index finger), three-finger-grip, four-finger-grip, one-hand grip and two-hand-grip. We also determined the hand used to grasp and wield the object when performing each action. For the grip to be judged the same for two actions performed using a given object, both the grip type and placement of the hand on the object had to be identical.

Two experimenters coded the action clips independently and then discussed the actions on which they had disagreements for grips. There was roughly 95% agreement between the experimenters prior to any discussion.

After comparing the grips used for each of the $O_{AFF\ 1\&2}$ on Tasks 1 and 2 (or Tasks 1 and 3 if the objects with both affordances were used in task 1, but not picked for the action in task 2) for each object with both affordances, the grips used for the two actions were categorized as either *same* or *different*. From these data, each of the $O_{AFF\ 1\&2}$ used on Task 1 could be placed in one of four categories (see Tables 4 and 5). (1) An $O_{AFF\ 1\&2}$ used for both actions with the same grip for both actions. (2) An $O_{AFF\ 1\&2}$ used for both actions with a different grip for the two actions. (3) An $O_{AFF\ 1\&2}$ used for only the first action, but with the same grip for both actions. (4) An $O_{AFF\ 1\&2}$ used for only the first action, but with a different grip for both actions.

Calculating a dependent measure. For each individual participant and each pair of affordances, we considered the $O_{AFF1\&2}$ that were identified as having the first affordance on Task 1 and then determined whether the object was used for the second affordance (Task 2). If the object was used spontaneously to perform both tasks, it was recognized as having both affordances. We then determined whether the grip used on both tasks was the same (grip type and location on the object) or different. If an object was recognized as having both affordances and the same grip was used for both tasks, it would be coded as a correct prediction (=1); if a different grip was used for the two actions, then it would coded as an error (=0). For objects that were recognized as affording the first action, but not the second action, if a different grip was used for the two actions, then this object would be coded as a correct prediction (=1), while if the same grip was used for both actions, the object would be coded as an incorrect prediction (=0). For each participant and each pair of affordances, we calculated the percentage of correct predictions by dividing the number of correct predictions by the total number of $O_{AFF1\&2}$ that were used on Task 1. Appendix 2 illustrates these steps.

Results

Experiment 2 examined the predictions that people would notice the second use for an object when the object was grasped in a similar manner for both actions; when the two actions required different grip configurations, participants would be less likely to notice the second action. The data presented in Tables 4 and 5 for the *scoop-pound* and *dig-cut* pairs of affordances respectively are consistent with these predictions. The numbers in the upper left (the frequencies of same grips for objects that were used in both Tasks 1 and 2) and lower right (the frequencies of different grips for objects that were used in Task 1 and but not in Task 2) cells were actions consistent with our prediction. Thus, our proposal made correct predictions for 83.7 % and 87.9 % of the objects for the scoop-pound and dig-cut affordance pairs respectively.

It would be inappropriate to perform a chi-square test on the data from Tables 4 and 5 because each participant contributed an unequal number of counts to the matrix. We settled on the following analysis: For each pair of affordances, we determined the percentage of correct predictions for each participant across the objects having both affordances. Because the data for the percentage of correct predictions were not normally distributed, the data were normalized by using an arcsin transformation (2*(arcsin(Sqrt X)). Keppel and Wickens (2004, p.155) suggest this as an appropriate data transformation when the dependent measure is a proportion and when the study has small sample size and large proportions. Both of these conditions are met in this study.

A one sample *t*-test was conducted to determine whether the percentage of correct predictions is significantly higher than chance (0.5 which was transformed to 1.571): for the scoop-pound affordances, $t\ (12) = 6.952$, $p < .001$; for the dig-cut affordances, $t\ (12) = 7.682$, $p < .001$. It appears that when participants noticed the second affordance for $O_{AFF\ 1\&2}$, they used the same grip to perform both actions significantly more often than chance; similarly, when the second affordance was not noticed, participants were more likely to use different grips for the two actions than the same grip. This outcome was consistent with our predictions.

Finally, we also found that when our main hypothesis failed to make a correct prediction (frequency counts in the upper-right and lower-left cells), participants were more likely (78.57%) to recognize the second affordance for an object, but would have used a different grip to perform the respective actions (lower-left cell), than fail to recognize the second affordance, but would have used the same grip (21.43%). Thus, our approach based on Neisser's notion of switching perceptual cycles also predicted situations in which participants' actions would have departed from our hypothesis.

The overall outcome shows that when the same grip was used to perform the two actions with the same object, participants were far more likely to detect the second affordance for an object; when different grips were (or would have been) used to perform the two actions, participants were less likely to use the object to perform the second action. When the grip and location of the fingers on the object were the same for performing the two actions, participants were far more likely to recognize the second affordance than when the grips were different. On the other hand, when the second affordance of an object was not noticed, participants were more likely to use a different grip when performing the second action. This outcome is consistent with our prediction that whether a second affordance for an object is detected depends on the similarity of the second goal directed action to the one previous performed with the object.

Affordances specify the possibilities for how a prospective actor might interact with available objects in performing a goal directed action. If information about an affordance is available, the problem becomes one of understanding why that information might not be detected on some occasions. Neisser's (1976) notion of a perceptual cycle has provided a useful tool for understanding the data obtained in this experiment as well as in our previous work (Ye et al., 2009, and Experiment 1 of the current study). The pickup of information entails exploratory movements that are part of a perceptual cycle, whereby the detection of information for an affordance leads to action, which in turn may reveal more information about affordances for the layout of surfaces in the environment. The outcome of Experiment 2 indicates that the perception of a complex goal-directed action entails perceiving component affordances for actions that are embedded within the goal-directed action, for example, the grip used to contact the object, where on the object the actor gripped the object and possibly how the object might be wielded. When the component actions comprising two complex goal-directed actions involve similar grips and contact points on the object, people were more likely to notice the second affordance for an object. Thus, the perception of an affordance for a complex, goal-directed activity entails perceiving those affordances embedded within that complex action. Perception is embodied in the potential actions afforded by the objects and events that people encounter.

EXPERIMENT 3

Experiment 3 replicated Experiment 2 using both Chinese and American students. The outcome of Experiment 2 should be replicated for the American students. However, with respect to the Chinese students, this experiment is exploratory: In Experiment 1 we found that Chinese students were more likely to notice that some objects afforded both actions than the American students. Based on Experiment 1, we might expect to find that Chinese students would use more $O_{AFF\ 1\&2}$ than the American students. However, it is also possible that when the task required participants to interact with the objects that the Chinese students might perform more like the American students.

Method

Participants. 14 American Miami University undergraduate students and 14 Miami University students from China participated in this study. Participants who were enrolled in the introductory psychology course were given credit toward fulfilling a course requirement. The remaining participants were paid $10 for their time.

All of the Chinese participants were born in China and had lived in the United States for an average of 7 months (range = 2-24 months). The age range was from 18 to 29 years old (M = 22). 64% (9) of the Chinese students were undergraduates and only five were graduate students. Most of the undergraduates had just started their first semester at Miami University. The Chinese students had been studying English (in China) for an average of 11 years and were fluent in English. However, 57% (8) of the Chinese participants had never taken a course taught in English prior to enrolling at Miami University.

Materials. The two pairs of affordances used in Experiment 2 were again used in this experiment: *Dig-with/Cut-with* and *Scoop-with/Pound-with*. However, there were several minor changes in the objects used. Five of the objects having only one affordance were eliminated. Observations from Experiment 2 showed that the hat and bottle were rarely used for scooping; they were replaced by a *small pie tin*. The log was removed as an object to pound with and dental floss was removed as a cut-with item and the glass cup was eliminated as dig- with for similar reasons. The final collection of objects used in Experiment 3 is listed in Table 6.

The second change was in the materials with which participants interacted with in the pounding and digging tasks. For affordance pair of *scoop-with/pound-with*, Melba toast was substituted for the saltine cracker used for pounding action because it was firmer and would require that a stronger force be applied in order to crush it. Construction sand was used for the digging action because the soil used in Experiment 2 was so loose and soft that some participants tried to use dental floss for digging.

Procedure. The order of presentation of the two pairs of affordances was randomized for each participant. The instructions were read to the Chinese students in Chinese by the native Chinese experimenter (LY). Information obtained from a post experiment questionnaire showed that 64% (9) of the participants expressed a strong preference to receive the instructions in Chinese because they were more confident in their understanding of the instructions and felt they responded more spontaneously to the instructions to perform the actions.

The procedure was nearly identical to the one used in Experiment 2. As in Experiment 2, for each collection of objects, participants were allowed to pick up and explore the objects for a minute before they started Task 1. However, in this experiment the task instructions were modified so that participants were first instructed to identify the *most* suitable object for "*performing the action in a reasonably efficient way*."[2] After identifying that object and performing the required action, participants were then told to select other objects that could be used to "*perform the action in a reasonably efficient way*." In Task 2, participants picked up objects and performed the second required actions for the same pair of affordances. After the participant indicated that he/she finished, one experimenter would ask him/her to perform the Task 3, in which participants were instructed to use the $O_{AFF\ 1\&2}$ that the participant had not used for the second action but did use for the first action. These objects were treated as "missed" objects. The same procedure was repeated for the second pair of affordances. The order in which participants performed the two actions was counterbalanced. As in Experiment

2, the actions were videotaped, digitized and coded with respect to the grip used and the part of the object grasped. The dependent measure of correct predictions was calculated using the same procedures as in Experiment 2 (Appendix 2).

Results

The videotapes of each action involving $O_{AFF\ 1\&2}$ were viewed independently by two experimenters. The grip used for each action was determined using the same criteria employed in the previous experiment. For each $O_{AFF\ 1\&2}$ that was used to perform the first action, we also had a video clip of the object being used to perform the second action. The procedures from Experiment 2 were again used to determine: the numbers of same and different grips for objects that were spontaneously used to perform both actions as well as the number of same and different grips for objects which were only spontaneously used to perform the first action.

Tables 7 and 8 show the frequency counts for each of the four possible outcomes for the Chinese and American students respectively. Figure 10 shows the percentages of correct predictions for both affordance pairs for the Chinese and American students. Table 7 shows the results for the Chinese students. Correct predictions are found in the upper left and lower right cells. Our proposal correctly predicted 72% of the actions involving the $O_{AFF\ 1\&2}$, 68% for *Scoop-with / Pound-with* and 75% for *Dig-with /Cut-with*. For the American students, Table 8 shows that our proposal correctly predicted 77% of the actions involving the $O_{AFF\ 1\&2}$, 74% for *Scoop-with / Pound-with* and 80% for *Dig-with /Cut-with*.

As in Experiment 2, for each participant and pair of affordances, we determined the percentage of correction predictions for the $O_{AFF\ 1\&2}$. The resulting percentages were normalized using an arcsin transformation (2*(arcsin (Sqrt X)). A two-factor ANOVA (two affordance pairs/ within subject and one nationality/ between-subjects factor) was performed. As might be expected from Figure 10, there was no difference between two pairs of affordances, $F\,(1, 25) = .333$, $p = .569$, nor was there a main effect of nationality, $F\,(1, 25) = 0.46$, $p = .832$. Nor was there a significant interaction between affordance pair and nationality, $F\,(1, 25) = .297$, $p = .591$.

A second analysis was conducted to determine that whether the obtained percentages of correct predictions were above chance level. Because there was no difference between the two affordances pairs, the data were collapsed over both two pairs of affordances and compared with 0.5 (1,571 after transformation). For the Chinese students, t (13) = 4.792, $p < .0001$ (M= 2.13 which was 74% before transformation). For the American students, t (13) = 3.375, $p < .005$ (M= 2.12 which was 72% before transformation). This outcome of this analysis shows that the percentage of correct predictions was significantly above chance. In addition, our predictions were equally accurate for both Chinese and American students.

Predictions about the type of errors made. Neisser's notion of a perceptual cycle led to the prediction that when our proposal failed to make a correct prediction, we should expect few errors for those objects for which participants failed to detect the second affordance of an object on Task 2, but would have used the same grip to perform both actions. Table 8 shows that for the American students less than 17% of the errors involved using the same grip for $O_{AFF\ 1\&2}$ missed objects for the second action. However, for the Chinese students, Table 7 shows that 38% of the errors involved objects in this category; for the scoop-pound affordance pair, Chinese participants actually failed to notice $O_{AFF\ 1\&2}$ that they would have used the same grip for on Task 2.

Comparing the above analysis for the American participants with the results of Experiment 2, we find that the results for the two experiments were similar. In each case the percentage of correct predictions was significantly higher than the chance level of 0.5. Also, the frequency counts in Table 8 presented a same pattern as in Tables 4 and 5 from Experiment 2. Referring to Table 8, the upper left cell shows instances where people used the same grip for both actions in Task 1 and Task 2; the lower right cells shows instances where different grips were used in Tasks 1 3. The hand grips correctly predicted the chance of objects being picked with an average of 76.5%. Specifically, the accuracy of prediction was 73% and 80% respectively for affordance pairs of *Scoop-with / Pound-with* and *Dig-with / Cut-with.*

Comparing the Results of Experiments 1 and 3

Caution must be exercised when comparing the results of Experiments 1 and 3. The experiments used two very different methods: In Experiment 1 participants made judgments about whether an object might be used for a particular function without actually manipulating the objects, whereas action with the objects was central to Experiment 3. Experiment 1 used many fewer $O_{AFF\ 1\&2}$ than the third experiment. The Chinese students in Experiment 1 had, on average, been studying in the United States for a longer period of time than the students in Experiment 3. Perhaps, in part, because of these methodological differences, the two experiments present very different pictures of the performance of the Chinese and American students relative to one another.

Figure 11 depicts the marked differences obtained in Experiment 1 with respect to the number of $O_{AFF\ 1\&2}$ detected on Task 2, with the Chinese students identifying significantly more objects. The same figure reminds us that results of Experiment 3 were unequivocal in that the performance of students from both countries was nearly identical with respect to how they might interact with $O_{AFF\ 1\&2}$ in performing the two tasks. A two-factor ANOVA with two between-subject factors (Nationality, Experiment) was conducted to examine the performance of the Chinese and American students on Experiments 1 and 3. Neither main effect reached the .05 level of significance, *Nationality* ($F\ (1, 64) = 3.26$, $p = .076$); *Experiment* ($F\ (1, 64) = .157$, $p = .693$). That is, the percentages of $O_{AFF\ 1\&2}$ identified by Chinese participants (M =68.5) was not significantly larger than the percentage identified by Americans ($M = 53.64$) across over two experiments.

Figure 11 also reveals an interaction between Nationality and Experiment, $F\ (1, 64) = 199.78$, $p = .0001$, with a power of .99. The pairwise comparisons in the follow up simple effect test demonstrated that the Chinese students picked significantly more $O_{AFF1\&2}$ in Experiment 1($M = 78.1$) than in Experiment 3 ($M = 54.83$), $p < .006$. However, the American participants used more $O_{AFF1\&2}$ ($M = 69.99$) in Experiment 3 than in Experiment 1 ($M = 42.19$, $p < .006$) when they were only asked to make perceptual judgments without touching or manipulating the objects. When the two groups were actively interacting with objects in Experiment 3, the difference in the number of $O_{AFF\ 1\&2}$ was not significant (p<.09).

In summary, Experiment 3 replicated the results in Experiment 2 by showing the manner of grasping predict the chance of using objects for both actions. Both the Chinese and American used an object for two actions when the grips were the same and were more likely to miss the object when different grips would have been used.

GENERAL DISCUSSION

Research on the perception of affordances has largely focused on the detection of information for a *single*, goal directed action given in the layout of surfaces (e.g., *falling off at the edge of a cliff*, Gibson & Walk, 1960; *stair climbing*, Warren, 1984; *sitting*, Mark, 1987; Mark & Vogele, 1987; *stepping across gaps*, Jiang & Mark, 1994; *grasping*, Newell et al., 1989; *reaching*, Mark et al., 1997; *locomotion*, Shaw, Shaw, & Turvey, 1993). While these investigators understood that the layout of surfaces used in their research afforded other actions, that research did not examine how observers and prospective actors who participated in those experiments were able to distinguish the information for the intended affordance from information for other possibilities for action. Ye et al. (2009) reported the first affordance study to examine the perception of multiple affordances for an artifact and whether the perception of one of the artifact's affordances would make it less likely that another affordance would be noticed. Viewed from the perspective of affordances, long-standing research on functional fixedness shows that the perception of the affordance for an object's designed use reduces the likelihood of detecting secondary (nondesigned) affordances that would allow prospective actors to discover other actions afforded by the object. Ye et al. worked with a number of commonplace artifacts and extended that finding by demonstrating that the perception of one nondesigned affordance for an object could reduce the likelihood of detecting a second nondesigned affordance for the object.

Ye et al.'s results present a puzzle for the ecological perspective. The objects afforded the goal-directed actions studied by Ye et al—that is, the secondary affordances existed, regardless of whether they were perceived. When asked to judge whether an object afforded a particular action (without having referred to another action previously), observers rarely failed to notice the affordance. This indicated that information for the affordances exists and that under certain conditions the affordance could be perceived. Why, then, were observers less likely to notice the same affordance after having recognized another affordance previously?

The current investigation examined the possibility that a lack of experience in exploiting multiple uses for objects may have a role in explaining why the American college students from Ye at al.'s (2009) original experiment often missed the second affordance for an object. Americans tend to use artifacts and tools for a single function. The tool design often optimized for that function. In contrast, the artifacts and tools used by people from East Asian cultures are often designed and intended to be used to perform multiple functions. Chinese people would have more experience than American in using objects to perform multiple functions and thus would have more opportunities to detect information for multiple uses. Experiment 1 replicated Ye et al.'s first experiment with Chinese and American students studying at Miami University. The Chinese students were significantly better than the American students on Task 2 at identifying the second affordance of $O_{AFF\ 1\&2}$ (Figure 1). Still, the Chinese students were more likely to notice the second affordance for $O_{AFF\ 2}$ than for $O_{AFF\ 1\&2}$. And it is also important to note that the American students were able to detect a second affordance for more than half of the $O_{AFF\ 1\&2}$. How are we to understand the differences between the Chinese and American students in the first experiment? To formulate a viable explanation of the findings of Experiment 1 as well as Ye et al. (2009, Experiment 1), we will have to identify the conditions under which people will identify the second affordance for $O_{AFF\ 1\&2}$ and when they would fail to notice the second affordance.

Given that the affordances exist and that information for the affordances is also available, the challenge becomes one of understanding why information for the second affordance is detected on some occasions, but not others. The difficulty must lie in the exploratory activity entailed in the pickup of information. In this regard Neisser's (1976) notion of a *perceptual cycle* offers some guidance. In selective looking experiments Neisser and his colleagues found that observers could selectively attend to one of two superimposed events and, with practice in the task, notice an unusual occurrence in the unattended event (Bahrick, Walker, & Neisser, 1981; Becklen & Cervone, 1983; Littman & Becklen, 1976; Neisser, 1979; Neisser & Becklen, 1975). Neisser viewed switching attention between events as one of switching perceptual cycles entailed in information pickup. Ye et al. (2009) had effectively constructed a naturally-occurring analog of Neisser's selective looking experiments; instead of two temporally separate events being spatially superimposed by artificial means, a single, designed (man-made) artifact affords two (or more) goal-directed actions for a prospective actor. Ye et al. (2009) appropriated Neisser's concept of a perceptual cycle to capture the act of picking up information about a particular affordance. But under what circumstance would it become necessary to switch perceptual cycles to enable the pickup of information for another affordance?

Experiments 2 and 3 examined the following proposal. For an object that affords two goal-directed actions, a prospective actor should readily notice the second affordance (after using the object to perform the goal directed action afforded by the first affordance) when both actions involve similar ways of interacting with the object. That is, when the actor would use the same grip (defined with respect to the number of fingers in contact with the object and the location on the object where the hand is in contact with the object) for both actions, the same perceptual cycle could be activated and thus people would be likely to pick up information for the pair of affordances and spontaneously use the object to perform both actions. In contrast, when the two actions would entail different grips, the perceptual cycle would have to be modified in order to detect the information for each affordance. The act of changing perceptual cycles would reduce the likelihood of detecting the second affordance.

Experiments 2 and 3 used a task that required participants to grasp and wield the objects to carry out some of the goal-directed actions that had only been judged in Experiment 1. There were three notable findings: For the American students in both experiments, this proposal correctly predicted whether participants would notice the second affordance for more than 80% of the objects. The results of the American students were replicated in both experiments. A group of Chinese students also participated in Experiment 3. With respect of the predictions generated by this proposal, the Chinese students performed identically to the American students. And, both groups identified the second affordance for a comparable percentage of objects. Thus, the difference between the Chinese and American students obtained in the judgment task of Experiment 1 was not obtained when the task required participants to interact with the objects in performance of the goal-directed task.

Two questions emerge from the outcome of the current study: First, why did the Chinese and American students perform differently on Experiments 1 and 3 with respect to one another? Second, what do the results of Experiments 2 and 3 indicate about the perception of affordances in general and the challenge of perceiving multiple affordances for the same object?

Differences between the Chinese and American Students

When participants were limited to making judgments about affordances by only looking at the objects, the Chinese students were better able to detect the second affordance in $O_{AFF\ 1\&2}$ objects than American students. As proposed in the introduction, the Chinese students' prior experiences in using artifacts and tools for multiple functions may have facilitated their detection of the information for the pair of affordances. In the absence of the opportunity to interact with the objects, the object schemas previously developed by the Chinese students (in using objects to perform multiple functions) may have been better able to guide their visual exploration for picking up of information about affordances. As a result, for the judgment task of Experiment 1, they may have more readily noticed secondary affordances than their American counterparts. The tasks comprising the third experiment required participants to grasp and wield the objects. The actions performed with the objects allowed participants to continuously detect new information about an object's affordances, which then served to modify their schemas for the object and the goal-directed actions as well as redirect subsequent exploratory activities that facilitate the pick up of additional information. This continuous updating of the information about affordances would have been less likely to occur in the first experiment because participants only looked at the objects. In contrast, participants physical interaction with the objects in Experiment 3 likely facilitated detecting information about nondesigned affordances, especially for the American students who are thought to have had less experience in using objects to perform multiple functions (and consequently less flexible object schemas) than their Chinese counterparts. As a result, the performance of the American students was nearly identical to that for the Chinese students on the third experiment.

Neisser's notion of a perceptual cycle may also lend itself to a neuropsychological analysis using Milner and Goodale's (1995) taxonomy for classifying the two subsystems of the visual system: the *dorsal stream* has been implicated in perception for the purpose of *how* something might be used; and the *ventral stream* is associated with phenomenal awareness of what something is. When looking at an object, both subsystems respond: The ventral stream leads to phenomenal recognition of what the object is and that it belongs in a particular category (cup, spoon, hammer), which has a primary (designed) function associated with it. The ventral stream also enables awareness of (nonaction-based) object properties (size, shape, color, etc.) that describe the object. The phylogenetically-older dorsal system detects action-related properties that are relevant to how the observer as a prospective actor might interact with the object, i.e., reach for, grasp, wield, etc. Several neurological case studies call attention to this distinction between phenomenal awareness of what an object is and how a prospective actor might interact with it. Goodale and Milner's (1992) patient DF was unable to explicitly judge physical properties (size, shape) of an object, yet she could interact (grasp, wield) with the object to perform in task appropriate actions. Humphreys and Riddoch (2001) discuss several patients who collectively demonstrated a dissociation between awareness of what something is and how it might be used: Patient MP could identify objects when cued by action cues as opposed to object properties like color and shape; in contrast, GK and MB showed the opposite pattern. Sirigu, Duhamel, and Poncet (1991) point to a possible connection between these case studies and the judgment and action tasks used in the current study. Patient FB was able to use objects to perform complex actions and describe the individual movements comprising that action without being aware of the function for which the object being used. FB perceived affordances and could use the object appropriately to complete a task, but these actions occurred in the absence of phenomenal awareness of the function for which the object was being used. Riddoch and Humphreys (1987) reported a similar dissociation between semantically-guided judgments and nonsemantically-guided actions. Thus, evidence from neurological case studies raises the possibility that the judgment task used in Experiment 1 may have depended upon a different set of neurological processes than the action tasks used in Experiment 2 and 3.

With respect to the paradigm used in Experiment 1, Ye et al.'s (2009) third experiment provides some converging evidence for how the dorsal and ventral subsystems might be operating in performing the judgment task. Ye et al. replicated the action-based judgment task (their Experiment 1 and the current Experiment 1) and compared performance to a task in which their observers had to identify simple object properties (shape, color, angularity, curvature). Ye et al. reported the same preference for $O_{AFF\ 2}$ over $O_{AFF\ 1\&2}$ on the task of identifying objects with the second affordance. But when the judgments pertained to simple (nonaction related) object properties, there was no difference in the percentages of objects identified with both properties and objects with only the second property. Object-property judgments should engage only the ventral stream, whereas the action judgments would engage the dorsal stream, which would likely interact with the ventral stream in making the observer explicitly aware of the possibilities for action. The dissociation obtained by Ye et al (2009, Experiments 1 and 3) lends support to the applicability of this type of analysis for understanding the pattern of results obtained in Experiments 1 and 3 of the current investigation.

Both the judgment and manipulation tasks used in Experiments 1 and 3 respectively entail the perception of the possibilities for how the prospective actor might interact with the object and thus would require activity from the dorsal stream. Both tasks would also activate the ventral stream, which would enable the participant to recognize what an object is—that is, the category to which it belongs (e.g., glove, cup, hammer, spoon). It is also the case that the two systems communicate with one another.

For the American students the ventral stream might be expected to exert a stronger influence on the dorsal stream because they are familiar with artifacts and tools that are commonly used to perform only a single function. The ventral stream would be able to place the object in a particular category that has a primary (designed) function associated with it. In doing so, the ventral stream might constrain the activity of the dorsal stream in its search for objects with the needed affordances and thus make it more difficult to discover the second affordance. When making judgments, the ventral stream could exert a strong influence on the dorsal stream because the observer is not physically interacting with the objects in question. As a result the dorsal stream would be less likely to detect the affordances for the second goal-directed action. The ventral stream is also essential to the judgment task because observers have to make explicit their decisions about whether an object can be used for a particular function. In contrast, when the task entails using the objects to perform a goal-directed activity, the influence of the ventral stream may lessen because of the activity required of the dorsal stream. From the case studies cited above, it appears that the dorsal stream appears is able to detect information for goal-directed activities independently of the conscious awareness provided by ventral stream. Together, these proposals could explain why the American students often failed to notice the second affordance in the $O_{AFF\ 1\&2}$ in Experiment 1, but were more likely to identify the $O_{AFF\ 1\&2}$ when the task required them to perform a goal-directed action (Experiment 3).

Nisbett (2003, p.153) showed that ancient Chinese were not interested in categorization and understood objects by how people interacted with their field or environment. For the Chinese people, the world is always changing; therefore, Chinese would less likely to apply an abstract concept to objects and assign them into a specific group. The dispositions of objects are not stable so that an object should not be conceived as being used for only a single function. A ladle would not really make sense to a Chinese person, until it is related to a specific situational context and how the person is using the object. In one situation the ladle can be used for scooping, but in another situation it can also be used for piercing open a plastic bag when a knife or scissor is not available. Chinese people interact with the natural world by intuition and experience, rather than through constructed rules, representations or formal models (Nisbett, Peng, Choi, & Norenzayan, 2001). The Chinese students may have had more experience in using artifacts and tools for multiple functions. As a consequence, they might find it more difficult to place an object into a specific category, or be less inclined to do so (Nisbett, 2003). Thus, the ventral system would exert less influence over the dorsal system. As a result the dorsal stream might be more effective at noticing the secondary affordances and communicating this to the ventral steam, thereby resulting in their somewhat better performance on the judgment task in Experiment 1. But in Experiment 3 when the task involved interacting with the objects, the dorsal system takes on the same critical importance as it did for the American students, leading to comparable performance for both groups of students.

There is, however, a difference between the action-based tasks used in the current study and those employed in these neurological case studies (and more recent neuroimaging investigations). Previous work used coordinated actions involving tools and artifacts where the action involved the designed function of the tool or artifact. This was also the case with investigations with intact subjects that were designed to examine the embodiment of cognitive and perceptual processes (e.g., Creem & Proffitt, 2001; Tucker & Ellis, 1998; Symes, Ellis, & Tucker, 2005). Because the objects had an established *handle* by which they could be grasped in order to engage in the designed function, these investigators could distinguish appropriate and inappropriate ways of grasping the object. In contrast, the current study focuses on nondesigned functions for the objects. While sometimes grasping the object by the designed handle affords the nondesigned function, in other cases, our participants had to envision other places on which to contact the object as well as different grips to enable performance of the task. And in some cases there were multiple possibilities for how a goal-directed action might be performed. Thus, the action-based task used in Experiments 2 and 3 sets up a situation in which categorical information associated with the object's designed function might interfere with the efforts of the dorsal system to discover whether the object has the requisite affordances to carry out the nondesigned function. Unlike previous work, the current task has created a situation for which the ventral system's categorical knowledge of the artifact's designed function might interfere with the dorsal system's attempt to pickup information for the artifact's nondesigned function.

To summarize, in trying to understand the different pattern of results for the Chinese and American students on Experiments 1 and 3, we have attempted to place Neisser's notion of a perceptual cycle within the context of recent work in cognitive neuroscience that has identified dissociable functions of the visual system. To be sure, this argument rests on the premise that the Chinese students in our sample have more experience than the American students in using objects to perform multiple functions, something which we were unable to measure. Also, there is no direct evidence supporting this interpretation of the current findings with respect to the activity of the dorsal and ventral systems and their interaction. Still, this proposed explanation may be worthy of further investigation.

Finally, the distinction between structural or taxonomic properties of objects and functional properties also bears on recent work in the development of categorization abilities in young children. Deak, Ray, and Pick (2001), Defeyter and German (2003), Nelson, Frankenfield, Morris and Blair (2000) and Smitman, Van Loosbroek, and Pick (1987) have examined the effects of children's understanding of how objects are used for the development of categorization skills. Smitsman et al. (1987) studied the class inclusion problem in three and four-year old children. Although they could not solve the problem as typically presented with respect to structural/taxonomically-defined superordinate classes (e.g., shape, size, species), the children were able to provide the solution when the superordinate category was presented in such as way as to denote possibilities for action (e.g., "cuddliness"). The investigators suggested that affordances may serve a primary function in the emergence of categorization skills. German and Defeyter (2000) took a somewhat different tact. They devised a task which required children to use a box as something to climb on in order to complete the task. Younger children (4-5 years) more readily generated this nontypical use than somewhat older children (6-7 years) suggesting the primacy of object function as the initial basis for categorization. Findings like these point to a distinction between the perception of an object's function and physical properties.

What Does It Mean to Perceive an Affordance?

This study has dealt with seemingly simple, but deceptively complex goal-directed actions—scooping rice from one container to another, pounding a cracker, digging a hole in which to put a small ball, cutting Play-Doh into strips. Although none of these activities requires highly-skilled movements whose fine-tuning entails years of concerted practice, each activity entails acting upon several affordances as part of the overall goal-directed activity. This calls attention to the fact that several affordances are nested within the context of virtually every goal-directed activity. The act of picking up a cup to drink from entails *looking for* where the cup in located relative to the actor, *reaching for* the cup (by extending the arm), *grasping* the cup in the with the hand (what grip is used and where on the cup is the hand placed), *lifting* and *wielding* the cup so as not to spill the contents until the liquid can be poured into the actor's mouth. To use an object (cup) for realizing some goal (to drink from), the prospective actor has to detect information for each of the affordances nested within the goal-directed activity. These component affordances can be viewed *all of a piece*, that is, as the fluid assembly of actions entailed in realizing the goal and constrained by the goal itself. From this perspective the prospective actor looking to determine whether an artifact affords drinking from may not be explicitly aware of the set of component movements entailed in reaching the goal prior to initiating movement. At the same time how one of the component affordances is realized depends crucially on the actions that preceded it. The range of grips that can be used to grasp an object depends on the reach action used; how an object can be lifted and wielded depends on the grip and the placement of the hand. Also, during the process of executing each component action, the actor is constantly *fine-tuning* the action to incorporate the information obtained from the actual movements (as described in Neisser's perceptual cycle). The perception of an affordance entails perceiving the possibilities for a collection of actions that comprise the overall, goal-directed activity.

Reaching for and grasping may be thought of as privileged actions as they are involved in virtually any action involving an object. Perceiving that an object can be used to drink from entails perceiving how the object can be grasped so that the prospective actor can bring the edge of the object toward his/her mouth. The results of Experiments 2 and 3 point toward the prospective actor's sensitivity to at least one of the component actions, namely the grip (grip type and location at which the hand/fingers contact the object) used to hold the object. The experience of having previously interacted with the object to perform one action (scooping rice) affects the prospective actor's efforts to determine whether the same object could be used for another action. The results of both experiments showed that when the same grip was be used for both actions, both the American and Chinese students were more likely to notice the second use for the object than when the second action entailed a different grip. Also, participants rarely missed opportunities to use the object for the second action if the same grip would be used for both actions. This is not to say that participants never noticed they could use the object for the second action if a different grip had to be employed. However, this situation seemed more challenging: Tables 4, 5, 7, and 9 show that on Task 2 participants were less likely to use (spontaneously) those objects for which a different grip would be used (lower left cell) than fail to use those objects to perform the second action (lower right cell).

James Gibson's (1979) radical proposal was that information specifying an affordance for each prospective actor exists as a *complex primitive*, implying that the perception of an affordance does not entail a cognitive construction whereby information for the affordance is computed from more basic physical properties. The current research points to the complexity of the information for affordances to which Gibson alluded. To perceive that a cup affords *drinking from* entails perceiving the nesting of affordances for the component actions needed to bring the cup to your lips in order to pour liquid into your mouth. Seemingly simple, commonplace actions may be deceptively complex with respect to the component movements (actions) whose selection and control requires the pickup of information about each nested affordance. Much of this activity takes place beyond conscious awareness of these component acts, even prior to initiating movement; this observation points toward the involvement of the dorsal stream referred to in the preceding section.

Gibson (1979) argued that there is information for affordances which can be detected as a product of an individual agent's activity in his or her environment. This means that perception does not simply entail encoding features of the environment into some aspect of the perceiver's mind (e.g., memory). Insofar as perception is of affordances, then perception is embodied in the prospective actor's action capabilities. Tucker and Ellis (1998), for example, used an S-R compatibility task in which participants had to press a key with either their right or left hand depending on whether a picture showed an object in an upright or inverted orientation. They found that response time was facilitated when the handle of the pictured object was positioned such that the hand that would most likely to be used to grasp the object was used to press the key in response to the inversion task. Even though the response task had nothing to do with interacting with the object, the perception of the object seemed to be influenced by how the participant might interact with the object. Rosenbaum et al. (1990) found that how a person initially grasped an object reflected the outcome of the intended action so as to minimize awkwardness in the final position of the arm and hand. In the present study, Experiments 2 and 3 showed that whether an object is perceived to afford a particular action can be affected by how the prospective actor has previously grasped the object. Each of these findings demonstrates how perception can reveal possibilities for action.

For well over a decade evidence has been accumulating for the embodiment of cognitive processes, in particular, the involvement of motor representations as part of semantic categories: Klatzsky, Pelligrino, McCloskey and Doherty (1989) found that pictures of grip representations depicting how objects might be grasped could prime judgments made about the sensibility of verbally given action/object pairing, such as "to eat a carrot." Creem and Proffitt (2001) had participants pick up artifacts and tools under dual-task conditions in which they were performing either a task that involved semantic processing or visuospatial processing. Only the semantic task interfered with grasping the objects appropriately by the handles for which they had been designed to be used. When the competing task (semantic word-association task) occupied the semantic processes, there was less opportunity for the participant's grasping action to be constrained by knowledge of how the tool was designed to be used. This finding suggests that knowledge of the actions entailed in the designed use of the tool was embodied in the semantic knowledge about the tool.

Finally, if affordances are the sole product of the act of perceiving, as Gibson alluded to and others have explicitly argued (e.g., Stoffregen, 2000), then perception must also be *situated* in the goal-directed activities of an agent: The prospective actor's needs and intention direct the exploratory movements entailed in the pickup of information, which in turn direct the ongoing performance of the goal-directed activity and the subsequent detection of new information for continued control of the course of the action. What the actor knows, intends, and does depends upon the situation—including the layout of the environment (affordances), the social and cultural context, and the action capabilities and needs of an intentional, goal-directed agent. In the current investigation by situating the task in performance of goal-directed activities, a very different picture of perception was obtained compared to the task in which participants made judgments in the absence of situated action. This finding, when placed in the context of the growing body of literature on embodied cognition, has implications for the methods used to study the perception.

REFERENCES

Bahrick, L. E., Walker, A. S., & Neisser, U. (1981). Selective looking in infants. *Cognitive Psychology, 13*, 377-390.

Becklen, R. & Cervone, D. (1983). Selective looking and noticing of unexpected events. *Memory and Cognition, 11*, 601-608.

Chao, Y.-R. (1968). *A grammar of spoken Chinese*. Berkeley: University of California Press.

Chiu, L.-H. (1972). A cross-cultural comparison of cognitive styles in Chinese and American children. *International Journal of Psychology 7*, 235-242.

Chua, H. F., Boland, J., & Nisbett, R. E. (February, 2005). Attention to object vs background: Eyetracking evidence comparing Chinese and Americans. Poster presented at the *Annual Meeting of the Society of Personality and Social Psychology*, New Orleans, LA.

Creem, S. H. & Profitt, D. R. (2001). Grasping objects by their handles: a necessary interaction between cognition and action. *Journal of Experimental Psychology: Human Perception & Performance, 27*, 218-228.

Deak, G.O., Ray, S. D., & Pick, A. D. (2002). Matching and naming objects by shape or function: Age and context effects in preschool children. *Developmental Psychology, 38,* 503-518

Defeyter, M. A., & German, T. P. (2003). Acquiring an understanding of design: Evidence from children's insight problem solving. *Cognition, 89*, 133–155.

Dennett, D. (1987). *The intentional stance*. Cambridge, MA: MIT Press.

Dominoski, R. L., & Dallob, P. (1995). Insight and problem solving. In R. J.Sternberg & J. E. Davidson (Eds.). *The nature of insight*. Cambridge, Mass.: The MIT Press. [pp 33-62]

Duncker, K. (1945). On problem solving. *Psychological Monographs, 68*, Whole No. 270).

German, T.P., & Barrett, H.C. (2005). Functional fixedness in a technologically sparse culture. *Psychological Science, 16*, 1-5.

German, T. P., & Defeyter, M. A. (2000). Immunity of functional fixedness in young children. *Psychonomic Bulletin & Review, 7,* 707-712.

Gibson, E. J. (1988). Exploratory behavior in the development of perceiving, acting and acquiring knowledge. *Annual Review of Psychology, 39*, 1-41.

Gibson, E. J., & Walk, R. (1960). The visual cliff. *Scientific American, 202*, 64-71.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton-Mifflin.

Gibson, J. J., & Gibson, E. J. (1955). Perceptual learning: Differentiation or enrichment. *Psychological Review, 62*, 32-41.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences, 15*, 20-25.

Humphreys, G. W., & Riddoch, M. J. (2001). Detection by action: neuropsychological evidence for action-defined templates in search. *Nature Neuroscience. 4*, 84-88.

Ji, L. J., Peng, K., & Nisbett, R. E. (2000). Culture, control, and perception of relationship in the environment. *Journal of Personality and Social Psychology, 78*, 943-955.

Jiang, Y., & Mark, L.S. (1994). The effect of gap depth on the perception of whether a gap is crossable. *Perception & Psychophysics*, 56, 691-700.

Keppel, G. & Wickens, T. D. (2004). *Design and analysis: A researcher's handbook*, 4th edition. Upper Saddle River, New Jersey: Prentice-Hall.

Kinsella-Shaw, J. M., Shaw, B., & Turvey, M. T. (1992). Perceiving "walk-on-able" slopes. *Ecological Psychology, 4*, 223-239.

Klatzky, R., Pellegrino, J. W., McCloskey, B., & Doherty, S. (1989). Can you squeeze a Tomato? The role of motor representations in semantic sensibility judgments. *Journal of Memory and Language. 28*, 56-77

Littman, D., & Becklen, R. (1976). Selective looking with minimal eye movements. *Perception and Psychophysics, 20*, 77-79.

Luchins, A. S. (1942). Mechanisms of problem solving: The effect of Einstellung. *Psychological Monographs, 54(6)*, 248.

Luchins, A. S. (1945). Social influence on perception of complex drawings. *The Journal of Social Psychology*, *21*, 257 - 273.

Maier, N. R. F. (1930). Reasoning in humans: I. On direction. *Journal of Comparative Psychology, 10*, 115–143.

Maier, N. R. F. 1931, Reasoning in humans II: The solution of a problem and its appearance in consciousness. *Journal of Comparative Psychology, 12,* 181-194.

Maier, N. R. F. (1933). An aspect of human reasoning. *British Journal of Psychology, 24,* 114-155.

Mark, L. S. (1987). Eye height scaled information about affordances: A study of sitting and stair climbing. *Journal of Experimental Psychology: Human Perception and Performance,13,* 361-370.

Mark, L. S., Balliett, J., Craver, K., Douglas, S. D., & Fox, T. (1990). What an actor must do to perceive the affordance for sitting. *Ecological Psychology, 2*, 325-366.

Mark, L.S., Nemeth, K., Gardner, D., Dainoff, M.J., Paasche, J., Duffy, M., & Grandt, K. (1997). Postural dynamics and the preferred critical boundary for visually guided reaching. *Journal of Experimental Psychology: Human Perception and Performance,23,* 1365-1379.

Mark, L.S., Jiang, Y., King, S. S., & Paasche, J. (1999). The impact of visual exploration on judgments of whether a gap is crossable. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 287-295.

Mark, L.S., & Vogele, D. (1988). A biodynamic basis for perceived categories of action: A study of sitting and stair climbing. *Journal of Motor Behavior, 19,* 367-384.

Masuda, T., & Nisbett, R. E. (2001). Attending holistically vs. analytically: Comparing the context sensitivity of Japanese and Americans. *Journal of Personality and Social Psychology, 81*, 922-934.

Masuda, T., & Nisbett, R. E. (2006). Culture and Change Blindness. *Cognitive Science,* 30. 381–399

Masuda, T., Ellsworth, P. C., Mesquita, B., Leu, J., Tanida, S., & Van de *Veerdonk*, *E*. (2008). Placing the face in context: cultural differences *in the perception of* facial emotion. *Journal of Personality and Social Psychology*, *94*, 365–381

Milner, A. D., Goodale, M.A. (1995). *The visual brain in action*. Oxford, England: Oxford University Press.

Miyamoto, Y., Nisbett, R. E., & Masuda, T. (2006). Culture and physical environment: Holistic versus analytic perceptual affordance. *Psychological Science, 17*, 113-119.

Nelson, D.G.K., Frankenfield, A., & Morris, C. Blair, E. (2000). Young Children's use of functional information to categorize artifacts: Three factors that matter. *Cognition. 77*, 133-168.

Neisser, U., & Becklen, R. (1975). Selective looking: Attending to visually specified events. *Cognitive Psychology, 7*, 480-494.

Neisser, U. (1979) .The control of information pickup in selective looking. In A. Pick (Ed.), *Perception and its development. A tribute to Eleanor Gibson*. Hillsdale, NJ: Erlbaum Associates. (pp. 201-219).

Newell, K.M., Scully, D.M., Tenenbaum, F., & Hardiman, S. (1989). Body scale and the development of prehension. *Development Psychobiology, 22*, 1-13.

Nisbett, R. E. (2003). *The geography of thought: How Asians and westerners think differently--and why*. New York: The Free Press.

Nisbett, R. E., Peng, K., Chio, I., & Norenzayan, A. (2001). Culture and systems of thought: Holistic vs. analytic cognition, *Psychological Review*, *108*, 291-310.

Norman, D. A. (2002). *The psychology of everyday things*. New York: Basic Books.

Nosofsky, R. M., & Johansen, M. K. (2000). Exemplar-based accounts of "multiple-system" phenomena in perceptual organization. *Psychological Bulletin and Review 7,* 375-402.

Riddoch, M. J., & Humphreys, G. W. (1987). Visual object processing in optic aphasia: A case of semantic access agnosia. *Cognitive Neuropsychology, 4*, 131-185.

Rosenbaum, D. A., Marchak, F., Barnes, H. J., Vaughan, J., Slotta, J. D., & Jorgensen, M. J. (1990). Constraints for action selection: overhand versus underhand grips. In M. Jeannerod (Ed.), *Attention and performance XIII* (pp. 321-342). Hillsdale, NJ.: Erlbaum.

Schmitt, B., & Zhang, S. (1998). Language structure and categorization: A study of classifiers in consumer cognition, judgment, and choice. *Journal of Consumer Research, 25*, 108-122

Smitsman, A. W., van Loosbroek, E. & Pick, A. D. (1987). The primacy of affordances in categorization by children. *British Journal of Developmental Psychology. 5*, 265-273.

Sirgu, A., Duhamel, J., & Poncet, M. (1991). The role of sensorimotor experience in object recognition: A case of multimodal agnosia. *Brain, 114*, 2555-2573.

Stoffregen, T. A. (2000). Affordances and events. *Ecological Psychology, 12*, 1–28.

Symes, E., Ellis, R., & Tucker, M. (2007). Visual object affordances: Object orientation. *Acta Psychologa, 124*, 238-255.

Tardif, T., Shatz, M., Naigles, L. (1997). Caregiver speech and children's use of nouns versus verbs: A comparison of English, Italian, and Mandarin. *Journal of Child Language*, 24, 535-565.

Tardif, T. (1996). Nouns are not always learned before verbs: Evidence from Mandarin speakers' early vocabularies. *Developmental Psychology*, 32, 492-504.

Torenvliet, G. (2003). We can't afford it!: The devaluation of a usability term. *Interaction, 10*, 12-17

Tucker, M., & Ellis, R. (1998). ON the relations between seen objects and components of potential actions*. Journal of Experimental Psychology: Human Perception & Performance, 24,* 830- 846.

Vogotsky, L. (1962). Thought and language. (E. Hanfmann & G. Vakar, Trans.) Cambridge, Mass.: MIT Press.

Warren, W. H. (1984). Perceiving affordances: Visual guidance of stair climbing. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 683-703.

Walk, R., & Gibson, E. A.(1961). Comparative and analytical study of visual depth perception. *Psychological Monographs, 75*(15), Whole No. 519

Witkin, H.A., & Berry, J.W. (1975). Psychological differentiation in cross-cultural perspective. *Journal of Cross-Cultural Psychology*, *6*, 4–87.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9, 625-636*

Ye, L., Cardwell, W., & Mark, L. S. (2009). Perceiving multiple affordances for objects. *Ecological Psychology, 21*, 185-217.

Ye, L., Taliaferro, M., Spurling, V., & Mark, L. S. (June 2006). Perceiving multiple affordances. Paper presented at the *North American Meeting of the International Society for Ecological Psychology*, University of Cincinnati. Cincinnati, OH.

Zhang, S., & Schmitt, B. (1998). Language-Dependent Classification: The Mental Representation of Classifiers in Cognition, Memory, and Ad Evaluations. *Journal of Experimental Psychology, 4,* 375-385.

Footnotes

[1] Email exchanges with Kaiping Peng and Nisbett (2007 February) suggested that it would be preferable to use Chinese for the Chinese participants because the language used may affect how people think about the task, the actions and objects used (Ross,, & Wilson, 2002). The outcome of a experiment debriefing indicated that 80% (16 out of 20) preferred the Chinese instruction because they found it easier to comprehend the instructions and descriptions of the actions; also, they felt they could respond more intuitively, Three of these four participants, who had no language preference in which to conduct the experiment in English had taken at least two course taught in English for two or more years.

[2] In Experiment 2 participants were instructed to choose only those objects that they confident could be used to perform the intended action. These instructions were modified in Experiment 3: participants were told to select objects that could be used to *perform the action in a reasonably efficient way*. The reason for this change is that in Experiment 2, two participants did attempt to systematically try every object for each of the tasks, sometimes violating task constraints in doing so. To discourage this practice, the instructions for Experiment 3 were modified to emphasize that we wanted participants to consider whether the object could be used efficiently to realize the task goal.

Table 1

Four pairs of affordances and four trays used in Experiment 1

	$O_{AFF\ 1}$	$O_{AFF1\&2}$	$O_{AFF\ 2}$
Scoop-with	bowl	sea shell	pencil
vs.	helmet	ice scraper	chop stick
Pierce -with	measuring cup	ladle	nail
Pack-with	cloth towel	ski cap	Lego block
vs.	cotton Ball	wad of Paper	Yo-Yo
Play-catch-with	rice	neck pillow	trainer's tape (roll)
Mop-up-with	eraser	turkey baster	bottle
vs.			
Floatable	wash cloth	sponge	ping-pong ball
Pour-in-able	hot water bottle	swimming cap	Bracelet
vs.	plastic Bag	rubber glove	head Band
Stretchable	bottle	balloon	ace Bandage

Note. $O_{AFF\ 1}$ = object with only one affordance; $O_{AFF\ 2}$ = object with only the second affordance; $O_{AFF\ 1\&\ 2}$ = object with both affordances

Table 2

Experiment 1: Percentage of Identified Objects on Task 1
for Chinese Participants

	% Identified Objects in Task 1			
Pair of affordances	% $O_{AFF\ 1}$	% $O_{AFF\ 1\&2}$	% $O_{AFF\ 2}$	% $O_{AFF\ 1\&2}$
Scoop-with Pierce-with	93.33	61.67	91.83	61.57
Pack-with Play-catch-with	83.33	83.33	90.42	84.83
Mop-up-with Floatable	95	72.5	92.5	70.59
Pour-in-able Stretchable	98.33	93.33	96	93

Experiment 1: Percentage of Identified Objects on Task 1

for American Participants

	% Identified Objects in Task 1			
Pair of affordances	% $O_{AFF\ 1}$	% $O_{AFF\ 1\&2}$	% $O_{AFF\ 2}$	% $O_{AFF\ 1\&2}$
Scoop-with Pierce-with	95	66.67	87	23
Pack-with Play-catch-with	80	75	85	40
Mop-up-with Floatable	82.5	77.5	87.08	46.49
Pour-in-able Stretchable	95	91.67	92.08	62.02

Table 3

Two pairs of affordances and Two trays used in Experiment 2

	$O_{AFF\ 1}$	$O_{AFF1\&\ 2}$	$O_{AFF\ 2}$
	Scoop-with only	**Both actions**	**Pound-with only**
Scoop-with	mask	measuring cup	prism
	bottle	spoon	clamp
vs.	hat	sea shell	screw driver
	Small type box	horn	log
Pound -with	Ice tray	bowl	jaw bone
		ladle	
		Ice cream scoop	
		wood jar	
	Dig-with only	**Both actions**	**Cut-with only**
Dig-with	Bamboo	protractor	key
	tongs	CD	dental floss
vs.		ruler	hair clip
		ice scraper	glass cup
Cut -with		spoon	
		shoe horn	
		trumpet shell	
		fork	
		shovel	

Note. $O_{AFF\ 1}$ = object with only one affordance; $O_{AFF\ 2}$ = object with only the second affordance; $O_{AFF\ 1\&2}$ = object with both affordances

Table 4

Experiment 2: Pair of Scoop-Pound Affordances: Frequencies of same and different grips used summed over participants for objects with both affordances ($O_{AFF\ 1\&2}$) that were used for both actions and missed for the second action

Grips used for two actions	$O_{AFF1\&2}$ used for both action	$O_{AFF1\&2}$ missed objects for the second action
Same grip	61	1
Different grip	14	16

Table 5

Experiment 2:Pair of Dig-Cut Affordances: Frequencies of same and different grips used summed over participants for objects with both affordances ($O_{AFF\ 1\&2}$) that were used for both actions and missed for the second action

Grips used for two actions	$O_{AFF1\&2}$ used for both action	$O_{AFF\ 1\&2}$ missed objects for the second action
Same grip	77	5
Different grip	8	17

Table 6

	$O_{AFF\ 1}$	$O_{AFF1\&2}$	$O_{AFF\ 2}$
Scoop-with	mask	measuring cup	prism
		spoon	clamp
vs.	small pie tin	trumpet shell	screw driver
	Small type box	horn	
Pound -with	Ice tray	bowl	jaw bone
		ladle	
		ice cream scoop	
		wood jar	

Dig-with	bamboo	protractor	key
	tongs	CD	
vs.		ruler	hair clip
		ice scraper	
Cut -with		spoon	
		shoe horn	
		clam shell	
		fork	
		shovel	

Note. $O_{AFF\ 1}$ = object with only one affordance; $O_{AFF\ 2}$ = object with only the second affordance; $O_{AFF\ 1,\&2}$ = object with both affordances

Table 7

Experiment 3: For Chinese, the frequencies of same and different grips used summed over participants for objects with both affordances ($O_{AFF\ 1\&2}$) that were used for both actions and missed for the second action

	Grips used for Two actions	$O_{AFF\ 1\&2}$ used for both actions	$O_{AFF\ 1\&2}$ missed for the second action
Scoop vs. Pound	Same grip	21	10
	Different grip	9	19
Dig vs. Cut	Same grip	43	6
	Different grip	17	28

Table 8

Experiment 3: For American, the frequencies of same and different grips used summed over participants for objects with both affordances ($O_{AFF\ 1\&2)}$ that were used for both actions and missed for the second action

	Grips used for Two actions	$O_{AF\ F1\&2}$ used for both actions	$O_{AFF\ 1\&2}$ missed for the second action
Scoop vs. Pound	Same grip	31	3
	Different grip	16	22
Dig vs. Cut	Same grip	44	3
	Different grip	14	25

APPENDIX 1 (reproduced from Ye et al., 2009, Appendix B)

Procedures for Selecting the Objects Used in the Experiments

We were looking for objects in these experiments that met three criteria: (a) The object had to be able to fit on a tray along with other objects. Thus, the object could not be too big. (b) We had to be able to find an actual exemplar of the object. (c) We wanted objects whose primary use was not the one we intended to use in this experiment. We devised the following procedure to determine the primary use of candidate objects: First, we prescreened potential objects by asking a group of 20 college students to look at a word depicting a label for a common object and indicate as many uses for the object as they could think of. Here, we paid close attention to the first function identified for each object. If more than 90% of these participants chose a different function than we intended to use in our experiment, then we obtained an instance of that object. This collection of objects was used in a second screening procedure. A separate group of 30 college students was asked to examine these actual objects and identify what they believed "the primary use or function for each object was." We chose objects for the study where more than 90% (at least 27 out of 30) of the participants labeled the primary use of the object as different from the affordance we had intended to use in the study. The purpose was to identify objects whose primary function was not one embodied in the pair affordances for which exemplars would be identified in Tasks 1 and 2.

In retrospect this procedure proved somewhat problematic with the affordance of *scoop-with*. Although participants used a variety of different labels for the hand shovel, ladle, and spoon, we failed to notice that the various labels were all trying to denote what we refer to as scoop-with. This was especially true for the hand shovel. Thus, the objects used were not ideal in that we were using some of their primary affordances. However, an analysis of the data for Experiment 1 did not show an effect of order in which participants judged the affordances scoop-with/pierce-with. Our error might have biased participants to notice objects with both affordances after having judged pierce-with objects, thereby diminishing the difference between objects that could only be used to scoop-with compared with those that had both affordances. Curiously, our results indicated that this did not occur, which further substantiates the robustness of the essential finding of Experiment 1.

APPENDIX 2

Procedures Used to Determine the Dependent Measure

For each individual participant and each pair of affordances, we considered the $O_{AFF1\&2}$ that were identified as having the first affordance on Task 1 and then determined whether the object was used for the second affordance (Task 2). If the object was used spontaneously to perform both tasks, it was recognized as having both affordances. We then determined whether the grip used on both tasks was the same (grip type and location on the object) or different. If an object was recognized as having both affordances and the same grip was used for both tasks, it would be coded as a correct prediction (=1); if a different grip was used for the two actions, then it would coded as an error (=0). For objects that were recognized as affording the first action, but not the second action, if a different grip was used for the two actions, then this object would be coded as a correct prediction (=1), while if the same grip was used for both actions, the object would be coded as an incorrect prediction (=0). For each participant and each pair of affordances, we calculated the percentage of correct predictions by dividing the number of correct predictions by the total number of $O_{AFF1\&2}$ that were used on Task 1.

The table below illustrates these calculations for a sample participant. The first row shows the participant's actions with the icescraper, which was used for both Tasks 1 and 2. The same grip was used for both actions, which results in a correct prediction. The same is true for the sppon. The shoe horn, however, was only identified on Task 1. However, the same grip was used for both actions, resulting in an incorrect prediction. The fork was identified on both tasks, but a different grip was used, resulting in an incorrect prediction. The shovel was identified on only the first task. A different grip was used to perform both actions, resulting in a correct prediction. Finally, this participant failed to use the cup on task 1 and thus did not enter into our analysis. Thus, or this participant and pair of affordances, there were five objects identified on task 1. Of these five objects there were three correct predictions or 60% correct predictions. This percentage became the dependent measure for each participant and pair of affordances.

Object	Affordance 1 (Task 1)	Affordance 2 (Task 2)	Number of identified affordances	Grip (1=same, 0 = different)	Correct Prediction = 1 Incorrect prediction = 0
Ice scraper	1	1	2	1	1
Spoon	1	1	2	1	1
Shoe horn	1	0	1	1	0
Fork	1	1	2	0	0
Shovel	1	0	1	0	1
Cup	0	1	1		

Finally, these percentages of correct predictions were transformed using an arcsine transformation and a t-test was performed to test whether these percentages were significantly different from 50% (chance).

Figure 1. Experiment 1: Percentages of $O_{AFF\ 2}$ and $O_{AFF\ 1\&2}$ identified in Task 2 summed over the four pairs of affordances

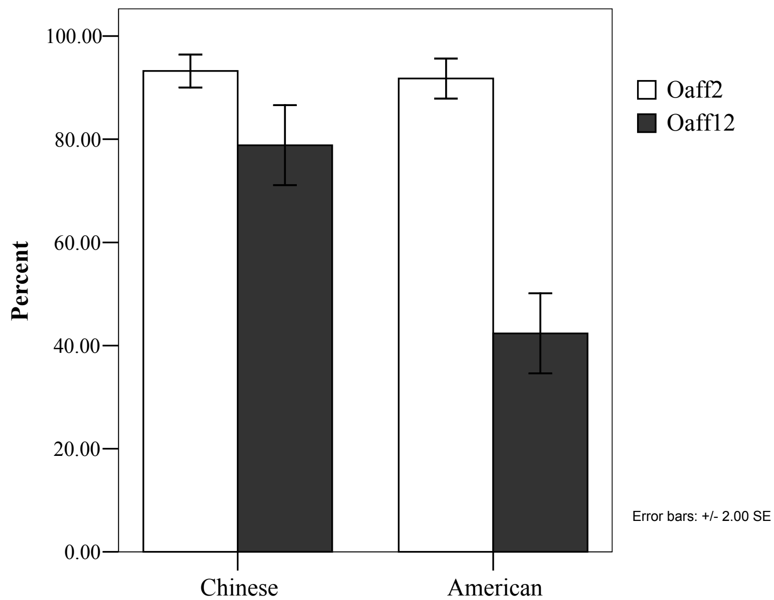


Figure 2. Experiment 1: Percentage of $O_{AFF\ 1\&2}$ identified by the Chinese participants on Task 2

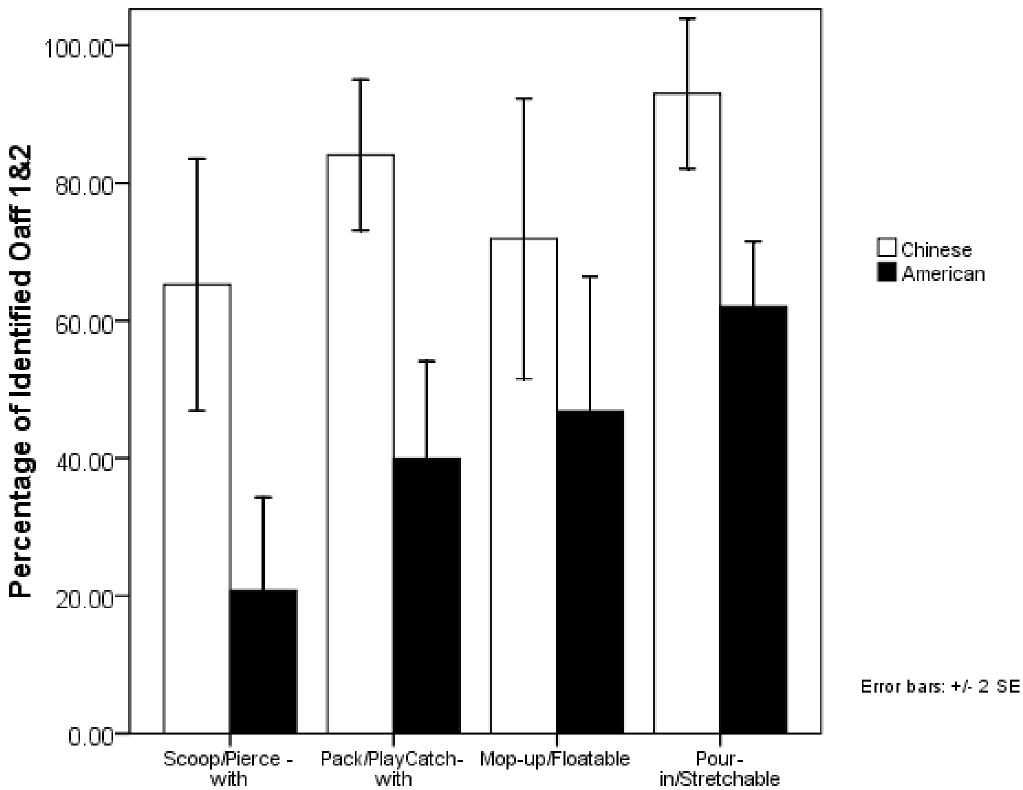


Figure 3 . Experiment 1: Percentage of $_{\text{OAFF 2}}$ identified on Task 2

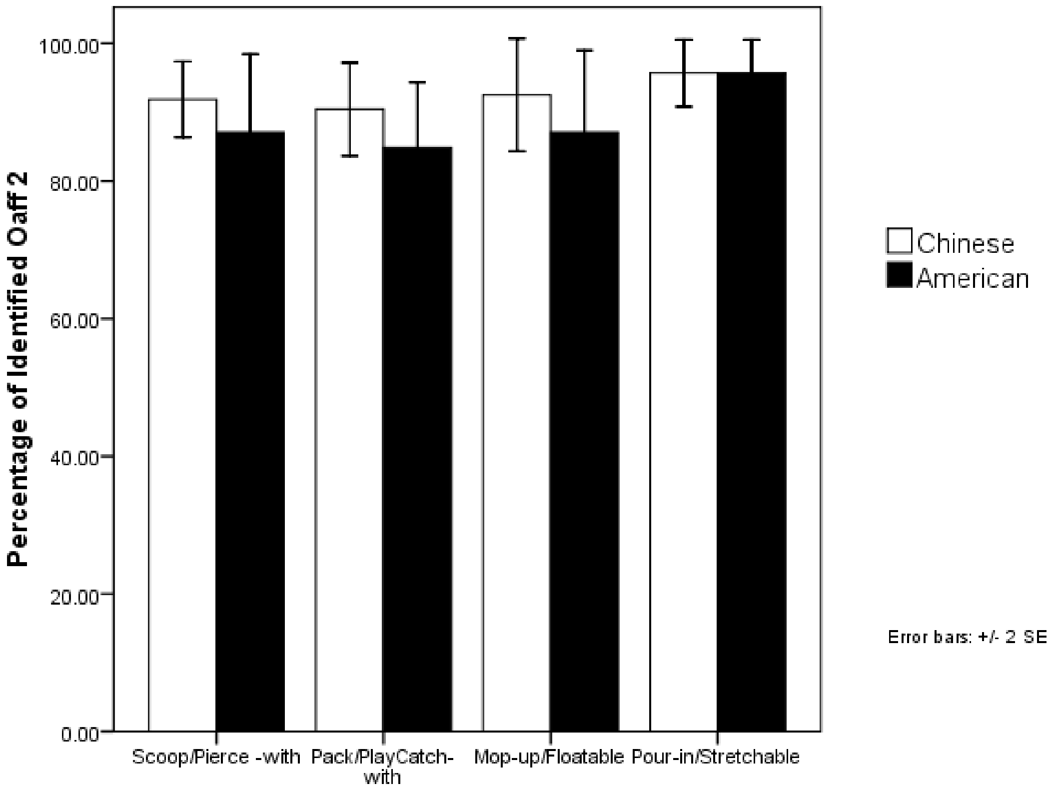
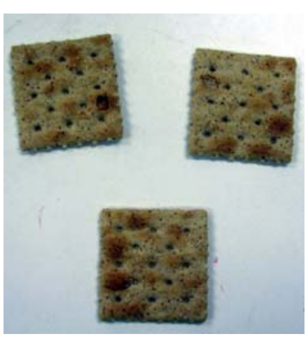


Figure 4. Experiment 2: Objects used for the *scoop-with/ pound-with/*

Figure 5. Experiment 2: Rice for scooping

Figure 6. Experiment 2: Crackers for pounding



Figures 7. Experiment 2: Objects used for the *Dig-with/ Cut-with*

Figure 8. Experiment 2: Soil for digging

Figure 9. Experiment 2: Play-Doh for cutting

Figure 10. The Percentage of Correct Predictions for $O_{AFF\ 1\&2}$ in Experiment 3

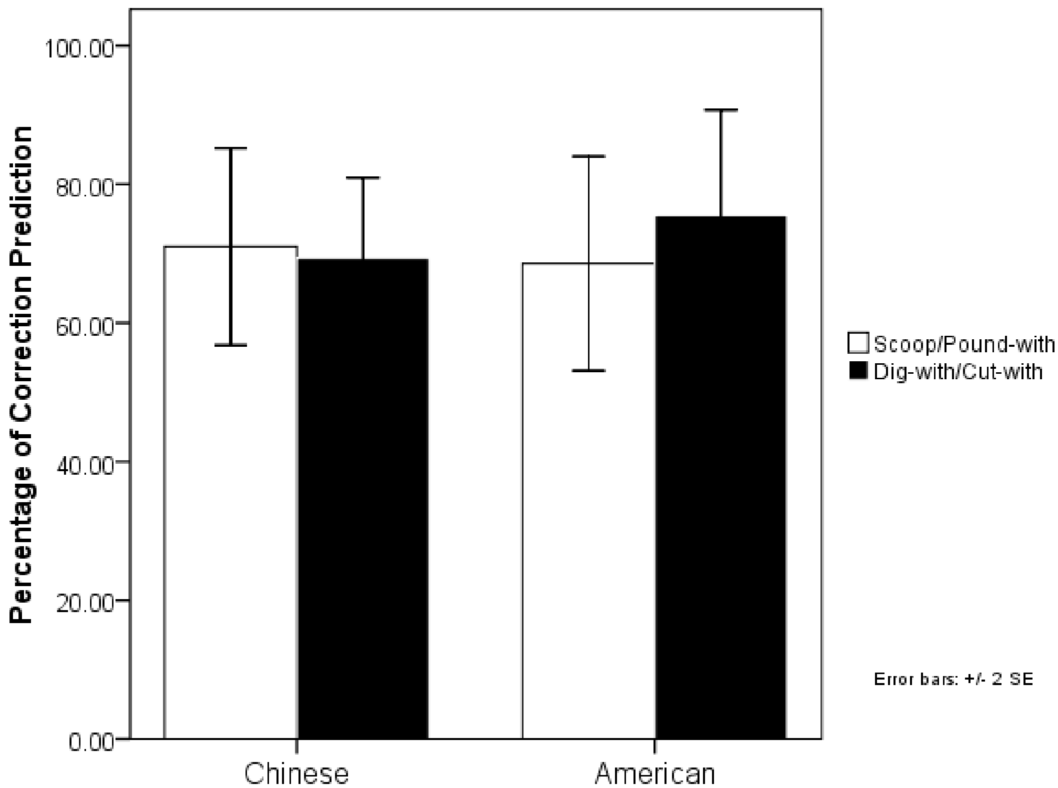


Figure 11. The Percentage of $O_{AFF\ 1\&2}$ Identified in Experiment 1 and Experiment 3 for the Chinese and Americans Students