**Manuscript accepted at Review of Philosophy and Psychology**
Published version: https://doi.org/10.1007/s13164-013-0146-3

# The Proper Function of Artifacts: Intentions, Conventions and Causal Inferences

**Sergio E. Chaigneau · Guillermo Puebla**

Received: date / Accepted: date

**Abstract** Designers' intentions are important for determining an artifact's proper function (i.e., its perceived real function). However, there are disagreements regarding why. In one view, people reason causally about artifacts' functional outcomes, and designers' intended functions become important to the extent that they allow inferring outcomes. In another view, people use knowledge of designers' intentions to determine proper functions, but this is unrelated to causal reasoning, having perhaps to do with intentional or social forms of reasoning (e.g., authority). Regarding these latter social factors, researchers have proposed that designers' intentions operate through a mechanism akin to social conventions, and that therefore both are determinants of proper function. In the current work, participants learned about an object's creation, about social conventions for its use and about a specific episode where the artifact was used. The function implemented by the user could be aligned with the designer's intended function, the social convention, both, or neither (i.e., an opportunistic use). Importantly, the use episode always resulted in an accident. Data show that the accident negatively affected proper function judgments and perceived efficiency for conventional and opportunistic functions, but not for designers' intended functions. This is inconsistent with the view that designers' intentions are conceptualized as causes of functional outcomes and with the idea that designers' intentions and social conventions operate through a common mechanism.

S. E. Chaigneau
Escuela de Psicología, Universidad Adolfo Ibáñez, Diagonal Las Torres 2640,
Peñalolén, Santiago, Chile
E-mail: sergio.chaigneau@uai.cl

G. Puebla
Universidad de Tarapacá, General Velásquez 1775, Arica, Chile

## 1 Introduction

Each time someone uses an artifact for its assumed purpose (e.g., a screwdriver to drive screws) they are demonstrating the remarkable capability of attaching a particular function to an artifact (i.e., function representation). Although there is evidence suggesting that function representation is not exclusively human Whiten et al (2005), it remains a core of human tool use Vaesen (2012). Furthermore, it has been argued that function representation plays a critical role in technology development. A distinctive feature of technology is its cumulative nature Tomasello (1999), and in order to develop cumulative technology it's necessary that users/designers attach a specific function to an artifact and through generations improve it Aunger (2010).

Given its relevance for tool use, function representation has received increasing attention in cognition (for work with children, see German, Truxaw, and Defeyter 2007; Kelemen and Carey 2007; Oakes and Madole 2008; for work with adults, see Bloom 1996; Chaigneau, Barsalou, and Sloman 2004; Chaigneau, Castillo, and Martínez 2008; Lombrozo and Rehder 2012). However, there are several still unresolved questions in theories of function representation. Here our aim is to shed light on some of these issues by drawing on ideas from the philosophy of technology, especially from Scheele's analysis of the social constitution of artifacts' functions (2005; 2006). This provides a foundation for an experimental situation that yields answers to these unresolved questions.

### 1.1 A Mapping of Functions: System and Proper Functions

According to Scheele, there are two ways to understand the artifact function. From one viewpoint, the system function of an artifact is the set of uses it affords. In this view, following Cummins (1975), a given function of an artifact is its final effect within certain causal system (e.g., a function of a hammer can be inserting a nail into a piece of wood, but also preventing a sheet of paper from being blown away). Note that in this view functions are relative to a certain background causal theory and, consequently, are extrinsic properties of artifacts. This is precisely the notion of function assumed in Chaigneau et al (2004). In this work, participants received information about makeshift artifacts' design history, physical structure, user goal and user action, and performed function ratings (e.g., does this scenario illustrate the function of a mop?). Results showed that participants reliably structured the information they received as a causal model, which in turn allowed them to infer whether the desired functional outcome could have occurred and from there to perform the required ratings.

From a different point of view, Scheele (2005) defines the proper function of an artifact as 'what it's meant for'. From this viewpoint, an artifact's function is an intrinsic property related to its own identity. This notion of function has a normative character. Accordingly, evidence by Casler et al (2009) suggests normative consequences for proper functions since early childhood. They demonstrated to 2- and 3-year-olds the functions of several artifacts. Later, when a puppet used the artifacts for a different purpose, children objected to his behavior more often than when the puppet used items properly, and did so in spite of his actions being effective.

While determining the system function of an artifact is certainly related to causal reasoning (Chaigneau et al 2004; Oakes and Madole 2008), the relation of causal reasoning and proper functions is less clear. As we will discuss next, several researchers conceive proper function as associated with the intentions of the artifact's designer and with social conventions about proper use, rather than with causal reasoning. In the next sections we describe two open questions about the attribution of proper functions.

## 1.2 Proper Functions, Causal Reasoning and Designer's Intentions

Several studies show that when people try to establish an artifact's proper function, their intuition points readily to designer's intentions (Bloom and Markson 1998; Gelman and Bloom 2000). If someone has to choose one of two functions as the real function of an artifact, she will probably choose the function originally intended by its designer over an equally plausible alternative function (German and Johnson 2002). Developmental research has found this trend emerges from about 6 years of age (German and Defeyter 2000).

Compelling evidence of the importance of designer's intentions comes from studies of functional fixedness and functional fluency. In Defeyter and German (2003), demonstrating an artifact's intended function made it harder to solve a problem that required using the same artifact in an alternative way for adults and 7-year-olds, but not for 5-year-olds. Correspondingly, in Defeyter et al (2007), demonstrating an artifact's intended function made it harder to generate multiple different functions for 7-year-olds, but not for 5-year-olds.

Although this research has highlighted the importance of the designer's intentions, the mechanism by which these intentions influence the attribution of proper functions remains an open question. One possibility is that the designer's intentions are an important factor in attributing proper functions because they are causes of artifacts' behavior and structure. This view is expressed in the design stance theory (Dennett 1990). In this theory, determining an artifact's function amounts to identifying which use it affords best. When, for whatever reason, there is no clear information about an artifact's behavior and structure, information about the designer's intentions can be used to infer the artifact's causal efficiency to bring about a given result. Note that in this theory, as far as the problem of the proper function is a matter of causal efficiency, the importance of designer's intentions qua intentions is secondary. In fact, Dennett has repeatedly argued that the attribution of functions should not rest in intentions, but only in optimality inferences about use (Vaesen and Van Amerongen 2008; Vermaas et al 2013). Cognitive researchers have often adopted this point of view (e.g., Ahn et al 2001) and evidence has been found that adults (Chaigneau et al 2004) and children (e.g., Matan and Carey 2001) do in fact use design information to guide inferences about current function.

Another possibility is that designers' intentions cannot be reduced to causal mechanisms. Designer's intention that the object belongs to a certain category may imbue the object with the category's function, separate from any causal reasoning (Bloom 1996; Gutheil et al 2004). Accordingly, in one study (Gutheil et al 2004), participants were shown artifacts broken beyond repair, such that they could no longer fulfill their functions with any degree of efficiency (e.g., torn paper plates). Adults in this study still counted broken artifacts as members of their corresponding categories, which is incompatible with the argument that people perceive design history as causing an artifact's current function and then use this when categorizing. Instead, those results suggest that design function was relevant for artifacts through intentional reasoning. Interestingly, the causal and intentional views remain quite separate in theory and in research, and we believe it's important to simultaneously examine them. Trying to understand how designers' intentions and causal reasoning relate when assigning proper function is a first goal of the current study. As we've discussed above, there is evidence that people reason about tool affordances, and in fact, there is evidence suggesting that they use affordances to infer intended use (Casler and Kelemen 2005). In contrast, our goal here points to inferences in the opposite direction, i.e., we look at how knowledge of intentional design affects inferences about affordances.

### 1.3 Conventions and Designer's Intentions

A recent concern in functional representation research is the role of social conventions in determining proper functions and its relation with designers' intentions. As Siegel and Callanan (2007) point out, artifacts are cultural objects made to satisfy the shared needs of a community. Consequently, proper functions should be sensitive to social conventions. Furthermore, in normal circumstances the designer's intentions match social conventions, opening the possibility that these are intrinsically related variables. Scheele (2005) seems to embrace this view. He proposes that generally designers are experts who create artifacts to accomplish particular goals, and that in this regard they are authorities. Thus, designers' intentions and social conventions might appeal to the same source of influence: authority, be it of an expert or of the group.

However, there are reasons to think that the designer's intentions influence the attribution of proper functions by a different mechanism than social conventions do. If social conventions and designers' intentions share a common mechanism, when they mutually contradict, their effects on proper functions should cancel out (i.e., what is the function of an artifact designed for A but conventionally used for B?). Yet, empirical evidence is mixed, with a study showing that conventions are equally powerful as design intentions for deter- mining proper function (Siegel and Callanan 2007), while another suggesting that design overwhelms conventions—at least in adults' judgments Defeyter et al (2009). Producing data that speak to this question is a second goal of the current study.

### 1.4 Marcel Scheele and the Social Constitution of Artifact Functions

The starting point of Scheele's (2005; 2006) analysis of functions is that artifacts, unlike biological entities (e.g., the heart), are objects used by human beings. Consequently, the notion of proper function is intrinsically related to the notion of use in the case of artifacts. According to Scheele, artifact use cannot be judged solely on the basis of causal efficiency considerations. Instead it is necessary to refer to the artifact's proper function in order to set its proper and accidental uses. With regard to proper functions, Scheele proposes that a full theory has to take into account social facts about artifact use (although his argument seems to focus mainly on the role of social conventions in proper functions, Scheele also argues that the role of designer's intentions can be traced to social facts). Importantly, for Scheele judgments about artifact use depend on proper functions, which in turn depend strongly on social facts about artifact use. This analysis becomes especially relevant in the case of artifact malfunction, where judgments about artifact use can be critical to assign responsibility for consequences of an artifact's malfunctioning.

To illustrate his analysis, Scheele gives an example concerning a "Figure-8", which is a simple metal devise used in mountaineering (see Fig. 1). He describes a person that uses the Figure-8 device to prevent a climber from accidentally falling when ascending a vertical mountain face (a use called belaying). The climber is attached to a rope, which is led through a series of anchors to a partner below. The rope crisscrosses the Figure-8 device, which is attached to the partner, such that if the climber above were to fall, the rope's friction with the belaying device would pull the partner upward and arrest the climber's fall (as illustrated in Fig. 2, panel a). Scheele then conceives a not unlikely scenario where the belaying device malfunctions and the climber falls with serious consequences, and the ensuing discussion in the community about whether the Figure-8 is really a belaying device or was made only for abseiling (i.e., using friction to descend in a controlled manner, as Fig. 2 panel b illustrates), and whether the climbing dyad did or did not use the Figure-8

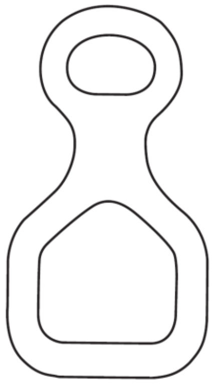

**Fig. 1** The Figure-8 device is a metal "8" shaped device used in rock climbing

correctly. Scheele goes on to propose that this is a discussion about the proper use of an artifact, and argues that this question cannot be answered solely based on causal considerations (i.e., if the Figure-8 is an efficient belayer or not), but requires taking into account social facts about the object's use (i.e., conventions about use and designer's intentions).

In our study, we used the Figure-8 example to model an experimental task that allowed us to simultaneously suggest answers to the two open questions we identified above: (1) whether proper function is determined by causal reasoning or by recourse to designers' intentions, and (2) whether designers' intentions and social conventions are both able to inform proper function through a common mechanism.

## 2 Task Overview

Based on Scheele's example, our participants received a single scenario that described in detail the physical structure of the Figure-8 device, its historical design function (abseiling or belaying), and an alternative use it could be put to (abseiling or belaying). Later, participants learned about a specific episode in which an individual used the Figure-8 for one of its possible functions and had an accident. Participants then answered three questions: (1) Would you agree that the Figure-8's real function is to be an X? (proper function question), (2) How efficient do you think the Figure-8 is as an X? (causal efficiency question), and (3) Do you think it is correct to use the Figure-8 as an X? (use question) (where X was once "abseiling device" and once "belaying device"). (There was actually a fourth question, but for clarity of presentation we defer its discussion to the Section 4.)

The main factor in our design had 4 levels (norm: normative, opportunistic, historical, conventional use). In the normative use condition, the Figure-8 was described as having been designed for one function (e.g., belaying), being convention-

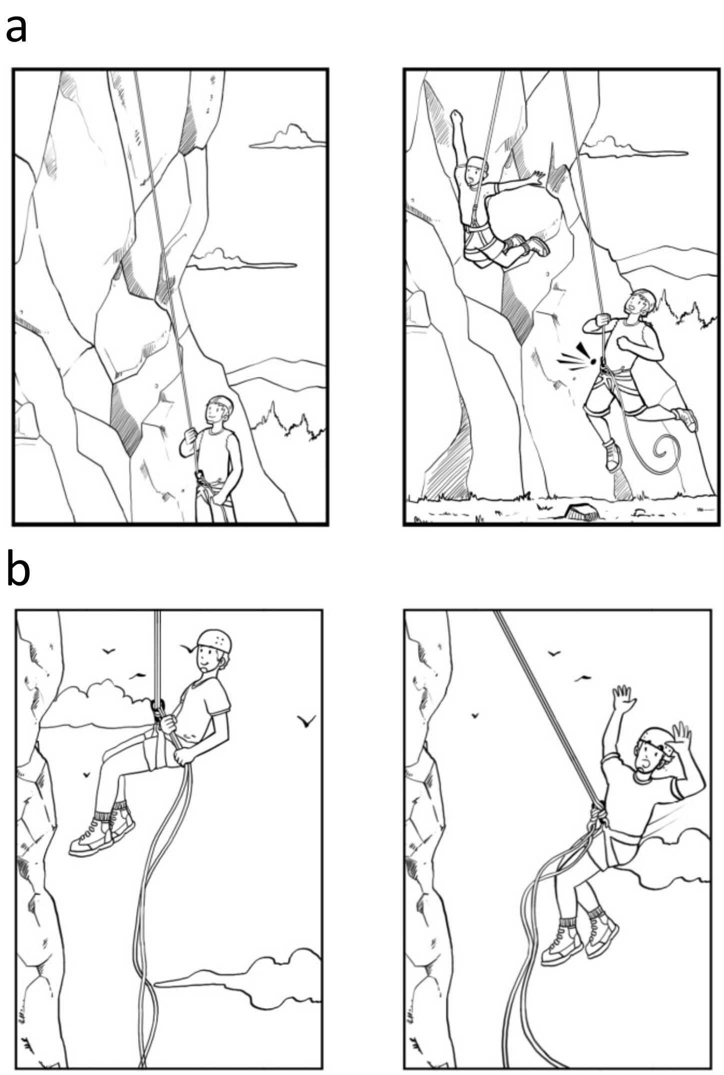


**Fig. 2** The Figure-8 device is a metal "8" shaped device used in rock climbing

ally used by all those in the user's climbing community for that same function (i.e., belaying), and later being used by the user for that same function (though it could have been used for a different function, i.e., abseiling, which was also described). In the opportunistic use condition, the Figure-8 was described as having been designed for one function (e.g., belaying), being conventionally used for that same function (i.e., belaying), but later being used by the user for the alternative function which was neither historical nor conventional (i.e., abseiling). In the historical use condition, the Figure-8 was described as having been designed for one function (e.g., belaying), being conventionally used by all those in the user's climbing community for a different function (i.e., abseiling), and later being used by the user for the historical, not the conventional function (i.e., belaying). In the conventional use condition, the Figure-8 was described as having been designed for one function (e.g., belaying), being conventionally used by all those in the user's climbing community for a different function (i.e., abseiling), and later being used by the user for the conventional, not the historical function.

## 3 Task Process Model and Hypotheses

Recall that the scenarios always described that an accident occurred when the object was used, independently from the participant's experimental condition. Critical for our experiment was the assumption that participants would use the information about the accident to infer the causal efficiency of the Figure-8 device for carrying out the function in which the accident occurred. We predicted that our participants would use information about the accident to reduce the artifact's perceived causal efficiency for carrying out the function in which the accident occurred in contrast to the perceived efficiency of the alternative function. For example, in the opportunistic use condition described above, the accident should lead participants to reduce the perceived efficiency of the Figure-8 for abseiling in general relative to its efficiency for belaying.

To better understand the underlying logic of how these inferences were used to test hypotheses, imagine you believe someone perceives a causal link between type X events and type Y events. To confirm your belief, you could ask that person to estimate the state of Y given the state of X (e.g., we could have given information about the state of the design history, the convention, or the current use and then ask for the possible state of the functional outcome). Instead, what we did in the current study was to provide participants with information about an instance where Y did not occur as expected (i.e., the accident) and asked them to estimate the ability of X to produce Y as expected (i.e., the causal efficiency question). To the extent that participants used knowledge of the accident to infer a lowered causal efficiency, it would indicate that they perceived a causal link from the putative determinant of function (designer's intentions, convention, user's intention) to the artifact's implemented function.

Recall that the first question we wanted to answer is how causal knowledge and knowledge about designer's intended function relate when people assign proper functions to artifacts. Two comparisons in our design are relevant for this question. One concerns the causal efficiency question. If knowledge of design history is conceived as a cause of functional outcomes, then the accident should promote inferences about the artifact category's inefficiency, both when the accident occurs in the historical and in the non-historical functions. Alternatively, if knowledge of intentional design relates to function through a mechanism different from a causal one, it should be insensitive to causal inferences, and no effects should be detected for historical and normative use conditions (where current use coincides with designer's intentions). A second comparison concerns the proper function question. If knowledge of the designer's intentions determines proper function via causal inferences of efficiency (as in Dennett 1990), then it should be considered less informative of proper function if there is direct evidence of an artifact's inefficiency. Contrastingly, if knowledge of the designer's intentions determines proper function via some non-causal mechanism, then the influence of the accident would be detected for non-historical functions (conventional and opportunistic use conditions) but not for historical functions (historical and normative use conditions).

Recall now that the second open question is what the relation between design history knowledge and knowledge of convention is. If both variables share a common source of influence, they should exhibit a similar response to the accident information. In our experiment, we were able to test this by comparing participants' answers to the proper function question in the historical use versus the conventional use conditions. In each condition the user is aligned with either the design history or with the group's conventional use, so these two conditions contrast both sources of knowledge. Yet another interesting comparison is between the opportunistic use and conventional use conditions. If conventional use determines proper function, then we should expect higher proper function ratings in the conventional use condition than in the opportunistic use condition.

Because we had three kinds of ratings (proper function, causal efficiency and use), our design also allowed us to test Scheele's proposal that judgments about whether use is appropriate or not are related to both causal efficiency and proper function, and that these make independent contributions. In other terms, according to Scheele, the question about correct use may receive a purely causal answer (i.e., the artifact is correctly used if it is used such that the physical layout will produce the expected outcome) but also a purely normative answer (i.e., the artifact is correctly used if done in accord to social norms about its use).

## 4 Method

### 4.1 Design and Participants

The design included 2 factors in a 4 (norm) by 4 (question) mixed factorial design, with the latter as the within-participants factor. We explained the norm factor earlier. For the question factor, each participant answered 4 questions by using 7-point rating scales. In three of those questions (explained earlier), participants informed the extent to which the function where the accident occurred and the alternative function: (1) were the artifact's real function (proper function question), (2) were efficient (causal efficiency question), and (3) reflected an appropriate use of the object (use question). A fourth question asked participants to judge the extent to which the user and the artifact's design were responsible for the accident (Do you think that X was the main responsible for the accident?; where X was once "the user" and once "the design"). We included this question because in Scheele's theory, similar to correct use, judgments of responsibility depend on social more than causal variables (i.e., for Scheele, using an artifact for something that it was not designed for, makes the user responsible for a possible accident). To control for the order of presentation, questions were presented in 1 of 4 Latin square orders. Further controls are linked to the design of the materials, and will be discussed next.

Participants were 64 undergraduate students who participated for credit in introductory psychology courses (29 from the Universidad Adolfo Ibáñez and 35 from the Universidad de Tarapacá).

### 4.2 Materials and Procedure

Scenarios were constructed by completely crossing whether the Figure-8 was described as designed either for abseiling (A) or for belaying (B), whether it was conventionally used by a rock climbing club either for A or for B, and whether it was actually used by a particular club member for A or for B. This generated 8 scenarios, which combined with the 4 Latin square questions orders, resulted in 32 final scenarios. Scenarios where all three (design, convention and current use) are the same function (A or B), correspond to the normative use condition; scenarios where design and convention share the same function but current use does not, correspond to the opportunistic use condition; scenarios where design and current use share the same function but convention does not, correspond to the historical use condition; and scenarios where convention and current use share the same function but design does not, correspond to the conventional use condition.

Each participant received a single scenario to evaluate, proceeding at a self-paced rate. After receiving instructions and an explanation of the rating scales they would use, participants learned, always in the following order: (1) that the Figure-8 device (shown to them in drawing) was designed for a given function (either A or B, illustrated verbally, in drawing, and in a 41 s video showing an actual use of the artifact for that function); (2) that it could be used for an alternative function (either A or B, illustrated verbally, in drawing, and in a 41 s video showing an actual use of the artifact for that function); (3) that in a particular rock climbing community, all members used the artifact for one of those functions, and none used it for the other; and (4) that a specific member of the community used it for one of its possible uses and suffered an accident. The accident was described verbally and in drawing, and the mechanism that explained it was the same for the abseiling and for the belaying function, i.e., the long rope that ran through the Figure-8 was twisted and got blocked in the device. For the abseiling function, this turned the downward motion into a pendular motion, making the climber hit the rock wall. For the belaying function, this made the partner below to be thrusted upward, making that individual hit the wall (accidents are illustrated in Fig. 2).

A summary of the events remained in view during ratings. This prevented our task from becoming a working memory task. The summary simply reminded participants of the events (for the conventional use condition the summary read, e.g., "Recall that the 'Figure-8' was designed for belaying; that it can also be used for abseiling; that everyone in the club uses it for abseiling; and that the user used it for abseiling and had an accident.")

Questions were presented in one of the 4 orders. Each question required participants to perform 2 ratings. For the proper function question, participants rated each function (i.e., abseiling, belaying) on a 7-point scale as to whether it was the artifact's real function (1 = completely disagree that it is the real function, 7 = completely agree). For the causal efficiency question, participants again rated each function regarding the artifact's efficiency for that function (1 = completely inefficient, 7 = completely efficient). For the correct use question, participants rated each function as to whether it was correct to use the artifact for that function (1 = completely incorrect, 7 = completely correct). For the responsibility question, participants rated the extent to which the user and the design were responsible for the accident happening (1 = completely disagree that it is responsible, 7 = completely agree). Ratings had to be performed one at a time, and participants could not change their responses after providing them.

## 5 Results

Before submitting data to analysis, we computed 4 delta scores, one for each pair of ratings for the 4 questions. For the responsibility question, we subtracted ratings for the design's responsibility from ratings for the user's responsibility. Thus, negative scores reflected a greater responsibility for the design than for the user in the accident occurring. This was our *delta responsibility* variable. For the other 3 questions, we subtracted ratings for the alternative function (the function not involved in the accident) from ratings for the function involved in the accident (i.e., *delta function*, *delta efficiency*, *delta use*). A negative delta score reflected the extent to which knowledge of the accident promoted negative inferences about proper function, causal efficiency and correct use. Thus, our dependent variables were not direct ratings. Instead, they reflect the effect that knowledge of the accident produced on those ratings. Some researchers argue that proper function judgments are fundamentally linguistic in nature (Malt and Paquet 2013; Malt and Sloman 2007), and do not reflect underlying conceptual structure. Using the interference of different kinds of information in causal inferences as dependent variable instead of direct ratings (e.g., a naming question) makes our study less susceptible to the critique that our data result from the way in which people pragmatically understand questions about proper function.

Preliminary data analyses suggested that delta responsibility was unrelated to our manipulation. In fact, submitting delta responsibility to a one-way ANOVA with norm as its single factor (4 levels), revealed that mean delta responsibility was always positive and significantly different from zero ($F(1,60) = 9.67$, $MSe = 6.62$, $p = .003$, $R^2 = .14$, power $= .86$), and that there were no differences across conditions of the norm factor ($F < 1$). This means that participants always viewed the user as more responsible for the accident than the design, independently from the condition they were in. In consequence, we did not consider responsibility data in further analyses.

Delta scores for the other three questions were submitted to a 4 (*norm*) $\times$ 4 (*question order*) $\times$ 3 (*delta scores*) mixed ANOVA, with repeated measures on the latter factor. Importantly for us, there was no main effect of question order ($F(3,48) = 1.05$, $MSe = 13.59$, $p = .38$, $R^2 = .06$, $power = .27$) and it did not enter into any 2 or 3 way interactions. For the order by norm, and order by delta scores interactions, $F < 1$. For the order by norm by delta score interaction, $F(18,96) = 1.27$, $MSe = 2.55$, $p = .23$, $R^2 = .19$, power $= .79$. We consequently collapsed the order factor and continued our analyses without taking it into account any further.

Recall that the central hypothesis that our other predictions rested upon was that participants would use the accident to make inferences about causal efficiency. Data suggests that this indeed did occur. Delta efficiency data was submitted to a one-way ANOVA with norm as its factor. Results showed a main effect of norm ($F(3,60) = 7.27$, $MSe = 3.48$, $p < .001$, $R2 = .27$, power $= .98$). Importantly, as Fig. 3 illustrates, the ANOVA intercept showed that the overall delta efficiency mean score was negative and significantly different from zero ($F(1,60) = 49.5$, $MSe = 3.48$, $p < .001$, $R^2 = .45$, power=1), showing that, taken as a group, participants tended to perceive that the artifact was less efficient for the function associated with the accident than for the alternative function.

This last result allowed us to use the magnitude of the inference to test other hypothesis. In particular, recall that we hypothesized that if history is not treated by participants as a cause of function, then historical functions should be less affected by inferences of inefficiency promoted by knowledge of the accident than functions that are not historical (conventional, opportunistic). In fact, this is what we found (see Fig. 3). Planned comparisons showed that the average delta efficiency score of opportunistic use and conventional use was more negative than the average of the normative use and historical use delta scores ($t(60) = 2.16$, $p = .035$). This, by

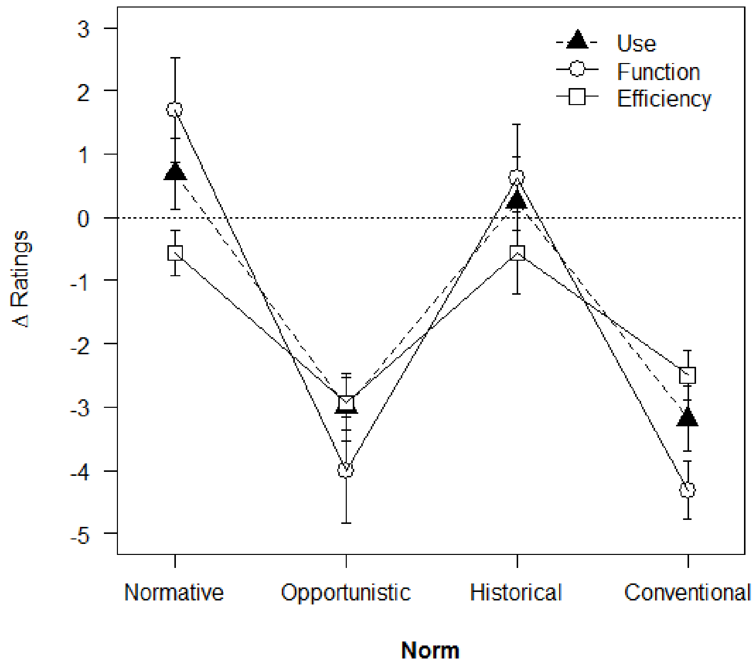


**Fig. 3** Mean delta use, delta function, delta efficiency ratings for 4 levels of the norm factor. Error bars are standard errors

itself, shows that historical function was being treated differently than other functions. However, being less affected by inferences of inefficiency does not mean that it is not affected. Stronger evidence of the special status of design history function would come from finding no detectable inferences prompted by the accident. Again, this is indeed what we found. Bilateral $t$ tests of whether delta efficiency scores were significantly different from zero, showed that opportunistic and conventional functions were significantly affected by the accident (respectively, $t(15) = -7.11$, $p < .001$; $t(15) = -6.46$, $p < .001$), whereas normative and historical functions were not (respectively, $t(15) = -1.59$, $p = .13$; $t(15) = -.86$, $p = .40$).

Recall that we wanted to address whether knowledge of designer's intended function determines proper function independently from causal inferences about efficiency. If this is true, then designer's intended function should be used to determine proper functions in spite of evidence of artifact's inefficiency, but information about inefficiency should affect negatively the extent to which non-historical functions are judged to be proper. To test this, we submitted delta function scores to a one-way ANOVA with norm as its factor. Results showed a main effect of norm

($F(3,60) = 16.76$, $MSe = 9.18$, $p < .001$, $R^2 = .46$, power = 1). Planned comparisons showed that, as predicted, the average delta function score of opportunistic use and conventional use was more negative than the average of the normative and historical use delta scores ($t(60) = 5.4$, $p < .001$). Furthermore, bilateral t tests of whether delta function scores were significantly different from zero showed that evidence of inefficiency negatively affected judgments of proper function when the artifact was used for a non-historical function (i.e., opportunistic and conventional use, respectively, $t(15) = -4.81$, $p < .001$; $t(15) = -9.5$, $p < .001$) and not when the artifact was used for its historically intended function (normative and historical use, respectively, $t(15) = 2.03$, $p = .06$; $t(15) = .74$, $p = .47$).

As previously stated, we wanted to address what the relation between design history and convention is, and whether both play a role in determining proper function. To this end, we compared delta function scores for the historical use condition versus the conventional function condition. If both sources of function representation are determinants of proper function, then we should find that the proper function question is answered in about the same manner in both conditions. We found support for the opposite conclusion. A planned comparison that contrasted the historical and conventional use conditions showed that participants in the conventional use condition reduced their judgments of proper function significantly more than participants in the historical use condition ($t(60) = 4.6$, $p < .001$). This contrast suggests that people view design history as a significantly more important determinant of proper function than conventional function. However, this does not mean that convention is not important. To gauge the importance of convention, an interesting comparison to make is to contrast convention against opportunistic function. If convention is a determinant of proper function, it should have a greater effect than an opportunistic function. To test this, we performed a planned comparison of delta function between the opportunistic use and the conventional use conditions. Results showed that proper function ratings in the conventional use condition were not more favorable for the conventional function than ratings for the opportunistic function in the corresponding condition ($t(60) = 0.3$, $p = .77$). In other words, participants viewed convention as less determining of proper function than design history, and did not view convention as more determining of proper function than an opportunistic function.

Finally, our data allowed us to address whether judgments of artifact use are related to proper function and to causal efficiency, with each making independent contributions to judgments of use. To test this, we computed a stepwise linear multiple regression with delta use as dependent variable, and delta function and delta efficiency as predictors, across all conditions in our experiment. Both predictors entered into the equation, and were positively correlated with delta use scores (for delta function, $\beta = .62$, $t = 7.21$, $p < .001$; for delta efficiency, $\beta = .31$,

$t = 3.59$, $p = .001$). The model produced an $R^2 = .72$, which was statistically significant ($F(2,61) = 83.38$, $p < .001$). Notably, though both predictors were correlated ($r = .64, n = 64, p < .001$), each made independent contributions to delta use scores as shown by semipartial correlations (for delta function, $sr = .48$ and for delta efficiency, $sr = .24$).

## 6 Discussion

According to our first set of results, information about designer's intentions strongly impacts the artifact's proper function in spite of an accident occurring while using the artifact for this same function. This result is in line with evidence suggesting that the importance of the designer's intentions in functional reasoning goes beyond its inferential value regarding the artifact's causal efficiency to bring about the sought outcome (Chaigneau et al 2008). Furthermore, artifacts' originally intended function is unaffected by inefficiency inferences promoted by an accident while using the artifact to accomplish it.

A post hoc explanation that links this last result to those of other researchers is that designers' intentions can either promote or prevent causal reasoning about artifacts' functions. On the one hand, when there is no clear information about the physical structure or the performance of an artifact, designer's intentions can promote causal reasoning towards inferring causal efficiency for the artifact's originally intended function. In fact, a number of previous results regarding to the importance of designer intentions can be seen in this way (for a review, see Chaigneau et al 2004). On the other hand, in the case of artifact malfunction, information about designer's intentions can prevent causal reasoning by blocking inferences of inefficiency for the artifact kind. To exemplify this, imagine a person that uses a knife to drive a screw and gets accidentally cut. According to our post hoc hypothesis, she will probably infer that knifes are inefficient to drive screws. Instead, if the person uses a screwdriver and cuts herself, she probably won't infer that all screwdrivers are inefficient to drive screws and will generate some alternative explanation for the malfunction episode (e.g., she might think that only this particular item was a bad screwdriver or that she failed to use the artifact correctly). Results of functional fixedness and functional fluency studies can also be explained in this way. In functional fixedness studies (Defeyter and German 2003), information about the artifact's originally intended function blocks causal inferences about possible final effects of using an artifact in alternative ways. Correspondingly, in functional fluency studies (Defeyter et al 2007) this blocking of causal inferences by designers' intentions makes it difficult to generate new functions for an artifact. We think that this post hoc hypothesis deserves further research.

Regarding our second set of results, we found that information about designer's intentions overwhelmed information about the conventionality of functions (consistent with Defeyter et al 2009 and inconsistent with Siegel and Callanan 2007. Moreover, we found no effect of conventionality in the attribution of proper functions. These results speak against the possibility that designer's intentions and conventions share a common source of influence in functional reasoning about artifacts. Furthermore, efficiency judgments behaved differently relative to conventions as compared to designers' intentions. Information about the accident significantly reduced perceived efficiency for uses that followed social convention. Participants may have reasoned that if conventions were adopted based on the artifact's efficiency, then direct evidence of inefficiency argued against that conventionally presumed efficiency. In contrast, information about the accident did not significantly reduce perceived efficiency for uses that followed the designer's intentions. This suggests that designers' intentions were not regarded by participants as focused on efficiency concerns.

Finally, our third set of results showed that artifact use judgments were related to both proper function and to causal efficiency. Moreover, the relationship between proper function judgments and artifact use judgments were, to a considerable degree, independent. We do not want to make much of the size of the $\beta$ coefficients because the range of causal efficiency judgments was restricted relative to proper function judgments. Dispersion was lower for causal efficiency judgments ($SD = 2.13$) in comparison to proper function judgments ($SD = 4.01$), which reduces the ability of delta efficiency scores to correlate with delta use scores.

We acknowledge that our results rest on data from one object (the Figure-8) and that this opens up the question about their generality. However, the Figure-8 nicely controls for disparities in the way in which the object affords its putative functions, which is not easy to control for otherwise. Further studies may be necessary to extend our findings to other artifacts. However, it is clear that our data fail to support that proper functions are solely a matter of causal inferences of efficiency. It appears that knowledge of designer's intentions influences proper function judgments through a mechanisms that is not causal but presumably intentional. Additionally, designers' intentions apparently produce an effect on judgments of proper function that is different in magnitude and perhaps also in nature to the effect of social conventions about artifact use. Finally, though people do take efficiency into account when evaluating artifact use, knowledge about the artifact's proper function makes an independent contribution to their judgments. Overall, these results suggest that people's reasoning about artifacts' functions integrates causal efficiency and intentional reasoning processes in order to determine artifacts' proper function and to evaluate their use.

**Acknowledgements** This work was supported by grant 1100426 to the first author from the Fondo Nacional de Desarrollo Científico y Tecnológico (FONDECYT) of the Chilean government. We gratefully acknowledge Mark Nielsen for his useful comments on an earlier version of this manuscript. We are also grateful to Mauricio Ríos for help in data collection, and to Cristián Coo and Vicente Soto for their work in creating the materials, rock climbing videos, and also in data collection.

## References

Ahn Wk, Kalish C, Gelman SA, Medin DL, Luhmann C, Atran S, Coley JD, Shafto P (2001) Why essences are essential in the psychology of concepts. Cognition 82(1):59–69

Aunger R (2010) What's special about human technology? Cambridge Journal of Economics 34(1):115–123

Bloom P (1996) Intention, history, and artifact concepts. Cognition 60(1):1–29

Bloom P, Markson L (1998) Intention and analogy in children's naming of pictorial representations. Psychological Science 9(3):200–204

Casler K, Kelemen D (2005) Young children's rapid learning about artifacts. Developmental Science 8(6):472–480

Casler K, Terziyan T, Greene K (2009) Toddlers view artifact function normatively. Cognitive Development 24(3):240–247

Chaigneau SE, Barsalou LW, Sloman SA (2004) Assessing the causal structure of function. Journal of Experimental Psychology: General 133(4):601

Chaigneau SE, Castillo RD, Martínez L (2008) Creators' intentions bias judgments of function independently from causal inferences. Cognition 109(1):123–132

Cummins R (1975) Functional analysis. The Journal of Philosophy 72(20):741–765

Defeyter MA, German TP (2003) Acquiring an understanding of design: evidence from children's insight problem solving. Cognition 89(2):133–155

Defeyter MA, Avons S, German TC (2007) Developmental changes in information central to artifact representation: Evidence from 'functional fluency'tasks. Developmental Science 10(5):538–546

Defeyter MA, Hearing J, German TC (2009) A developmental dissociation between category and function judgments about novel artifacts. Cognition 110(2):260–264

Dennett DC (1990) The interpretation of texts, people and other artifacts. Philosophy and phenomenological research 50:177–194

Gelman SA, Bloom P (2000) Young children are sensitive to how an object was created when deciding what to name it. Cognition 76(2):91–103

German TP, Defeyter MA (2000) Immunity to functional fixedness in young children. Psychonomic Bulletin & Review 7(4):707–712

German TP, Johnson SC (2002) Function and the origins of the design stance. Journal of Cognition and Development 3(3):279–300

German TP, Truxaw D, Defeyter MA (2007) The role of information about "convention,""design," and "goal" in representing artificial kinds. New Directions for child and adolescent development 2007(115):69–81

Gutheil G, Bloom P, Valderrama N, Freedman R (2004) The role of historical intuitions in children's and adults' naming of artifacts. Cognition 91(1):23–42

Kelemen D, Carey S (2007) The essence of artifacts: Developing the design stance. In: Margolis EE, Laurence SE (eds) Creations of the mind: Theories of artifacts and their representation, Oxford University Press, pp 212–230

Lombrozo T, Rehder B (2012) Functions in biological kind classification. Cognitive psychology 65(4):457–485

Malt BC, Paquet MR (2013) The real deal: What judgments of really reveal about how people think about artifacts. Memory & cognition 41(3):354–364

Malt BC, Sloman SA (2007) Category essence or essentially pragmatic? creator's intention in naming and what's really what. Cognition 105(3):615–648

Matan A, Carey S (2001) Developmental changes within the core of artifact concepts. Cognition 78(1):1–26

Oakes LM, Madole KL (2008) Function revisited: How infants construe functional features in their representation of objects. In: Advances in child development and behavior, vol 36, Elsevier, pp 135–185

Scheele M (2005) The proper use of artefacts: A philosophical theory of the social constitution of artefact functions. Marcel Scheele, Leiden

Scheele M (2006) Function and use of technical artefacts: social conditions of function ascription. Studies in History and Philosophy of Science Part A 37(1):23–36

Siegel DR, Callanan MA (2007) Artifacts as conventional objects. Journal of Cognition and Development 8(2):183–203

Tomasello M (1999) The Cultural Origins of Human Cognition. Harvard University Press

Vaesen K (2012) The cognitive bases of human tool use. Behavioral and brain sciences 35(4):203–218

Vaesen K, Van Amerongen M (2008) Optimality vs. intent: limitations of dennett's artifact hermeneutics. Philosophical Psychology 21(6):779–797

Vermaas PE, Carrara M, Borgo S, Garbacz P (2013) The design stance and its artefacts. Synthese 190(6):1131–1152

Whiten A, Horner V, de Waal F (2005) Conformity to cultural norms of tool use in chimpanzees. Nature 437(7059):737–740