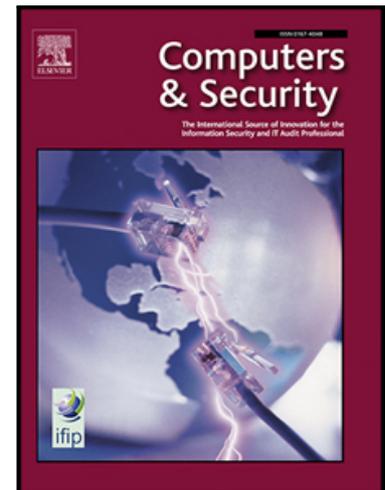


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“This is the Way ‘I’ Create My Passwords ...”

## Does the Endowment Effect Deter People from Changing the Way they Create their Passwords?

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### Abstract

The endowment effect is the term used to describe a phenomenon that manifests as a reluctance to relinquish owned artifacts, even when a viable or better substitute is offered. It has been confirmed by multiple studies when it comes to ownership of physical artifacts. If computer users also “own”, and are attached to, their personal security routines, such feelings could conceivably activate the same endowment effect. This would, in turn, lead to their over-estimating the “value” of their existing routines, in terms of the protection they afford, and the risks they mitigate. They might well, as a consequence, not countenance any efforts to persuade them to adopt a more secure routine, because their comparison of pre-existing and proposed new routine is skewed by the activation of the endowment effect.

In this paper, we report on an investigation into the possibility that the endowment effect activates when people adopt personal password creation routines. We did indeed find evidence that the endowment effect is likely to be triggered in this context. This constitutes one explanation for the failure of many security awareness drives to improve password strength. We conclude by suggesting directions for future research to confirm our findings, and to investigate the activation of the effect for other security routines.

**Keywords:** Password Creation Routines; Endowment Effect; Change Willingness; Psychological Ownership; Scenario-Based Survey

# 1 Introduction

Many security awareness and training drives are delivered with the best of intentions, and appear to be received enthusiastically by the recipients. Yet these same recipients either decline to change their regular routines, or change their behavior in the short term and then revert to their original routines [169, 3]. Some trainers attribute this kind of resistance to personal failings on the part of the recipients [48, 127, 178]. This kind of attribution does not help to resolve the situation.

Researchers and organizations respond to this situation by endeavoring to improve compliance [14, 151, 177]. Resorting to compliance enhancement efforts and rule-making is understandable when organizations are concerned that employee behaviors are placing the organization's information security at risk. Some propose dealing with resistance by imposing penalties for a failure to implement mandated security measures [87, 135]. Yet these kinds of approaches can backfire, leading to resentment [17, 153], perhaps because they unacceptably erode the employee's autonomy [45].

It would be helpful to understand the underlying causes of behavioral change resistance, rather than attempting to mandate new behaviors without acknowledging the nature and complexity of the human agent [139, 60]. If we want people to change the way they behave, we should endeavor to understand exactly why they are rejecting security-related advice. We will then be in a better position to formulate interventions to minimize the impact of the core causatives that manifest as reluctance, but are due to a far more complicated interplay of multiple factors.

Humans have good reasons for their behaviors, even if they perhaps cannot, or will not, articulate them. Sometimes people are not even conscious of reasons for their own behaviors [174, 179].

The endowment effect is observed when people feel *endowed* with a particular artifact, such that they are reluctant to exchange it for any substitute, even if the substitute is superior [90]. If the endowment effect is active, and people are asked to swap "their" artifact for another, they are more reluctant than can be expected by chance [96]. This suggests that the recipient of the artifact considers their endowed artifact to be more *desirable* than the other artifact, even if both command the same price in the marketplace. Moreover, this effect can occur almost immediately the person is endowed with the artifact.

The endowment effect is usually demonstrated by showing that people over-value an endowed artifact. This is evidenced by the fact that they will require more money (WTA: will-

ingness to accept) to relinquish the endowed item than the actual value of the item i.e. what someone else would reasonably pay for it (WTP: willingness to pay) [89, 97]. They essentially *over-value* the artifact: in their eyes it is more *valuable* than the objective reality would dictate, and more valuable than an offered substitute.

There is some evidence that the endowment effect does not only apply to physical artifacts, nor that it only applies in the lab. It has also been observed being triggered by people feeling endowed with other “artifacts” such as time and intellectual property [77]. Moreover, when some effort has been expended in obtaining a particular artifact, this exacerbates the endowment effect, suggesting that effort, and not merely the object itself, contributes to the triggering of the endowment effect [119].

We wanted to find out whether people feel endowed with their personal security routines. In essence, would they be *reluctant to exchange* them for other routines, and would they *over-value* them, in terms of the protection they afford? Clark [38] talks about people “owning” solutions they have come up with to problems, and certainly finding a personal way of dealing with passwords can be thought of as a solution. Does such ownership trigger the endowment effect in the password creation context?

The endowment effect, if it is indeed activated by effort invested in coming up with routines in the information security context, probably works in concert with other factors leading to change resistance. Osman *et al.* [126] point out that successful behavioral change campaigns require a suite of interventions to be devised and deployed. They also explain that it is often challenging to predict which combination of methods will be most efficacious. A better understanding of people’s rejection of security advice, and perceptions of risk, is the first step towards determining exactly which interventions are best to deploy. Here, we chose to focus on the potential influence of the endowment effect, which Arlen and Tontrup [10] consider to be a behavioral bias that can indeed be deactivated.

If we can confirm that this effect activates when it comes to security routines, proven techniques from other disciplines, where the efficacy of “muting” interventions have been confirmed [10], can be deployed to minimize its impact.

The one place where computer users encounter security risk is during authentication. The password, despite many reports predicting its imminent demise, still permeates our online lives [63]. One of the most ubiquitous pieces of advice given to computer users is to choose strong passwords that reduce the risk of not only data theft and damaged reputation, but also financial risks from ransomware attacks, loss of trust, and potential liability for damages from inadvertent hosting of Distributed Denial of Service attacks [53, 129, 172, 184]. Nonetheless,

the use of weak passwords is still prevalent [74]. We therefore chose password creation routines as the subject of our investigation. We describe a study we undertook to explore the existence and potential impact of the endowment effect in the password creation context. We report on our findings and conclude by suggesting directions for future research.

## 2 Reluctance to Switch

Cyber security is a relatively new phenomenon on an evolutionary scale, certainly much newer than many other areas of human risk management, such as managing physical safety or disease prevention. Due to its newness, it is thus reasonable to assume that the populace at large lacks sufficient knowledge and skills to secure their own information, systems and devices adequately [62, 138, 141, 143].

One risk mitigation technique is to enforce strength by disallowing weak passwords [154]. While this is an effective strategy, it does require installation on each and every system. The usual approach grants people the autonomy to choose a password themselves, having ensured that they know how to choose strong passwords. This strategy requires deliberate knowledge deficit-reduction efforts to be made [25, 156]. Information security researchers and practitioners consequently formulate educational and awareness drives to deliver knowledge of good practice. The aim is to improve security routines across the organization, thereby improving resilience and reducing risk [4, 76]. Governments also provide a great deal of advice to citizens in terms of how to practice good security hygiene [43, 73, 82, 120, 146].

Yet all these efforts do not seem to have been particularly successful in terms of reducing insecure behaviors [11, 36, 140]. Even those who do possess knowledge of “good practice” do not seem to be willing to change their usual routines [39, 94, 22]. It has become clear that an approach that relies solely on information provision is unlikely to be *sufficient* in terms of changing behavior [66, 69, 70, 88, 114]. It is interesting to note that the empirical findings by Warkentin *et al.* [176] showed that users prefer their own passwords over ones generated for them, even though the latter may be stronger.

As the field has come to realize that knowledge, on its own, is not the silver bullet in achieving behavior change, there have been attempts to manipulate the *choice architecture* to nudge people towards stronger passwords [51, 144]. While these manipulations show promise, they do not help us to understand the underlying reasons for reluctance to embrace stronger password choice routines.

Similar levels of change resistance manifest in other domains, too [30, 90, 81, 167]; security

behaviors are not unique in this respect. In this paper, we briefly review two prominent theories before introducing the explanation we investigated in our research: the endowment effect. We do not claim that other factors do not exert an influence; only that one influential factor might be the endowment effect, and that efforts to understand and minimize its impact might well reduce resistance.

## Reasons for Change Resistance in Security

The literature suggests a wide range of explanations for unwillingness to switch when people do indeed have the knowledge to behave securely. These include: intransigence, a lack of understanding of the importance of the activity, ignorance of the severity of potential consequences, or just plain laziness [3, 52, 64, 83, 111, 113, 188]. Infusing the situation with moral undertones can achieve the opposite of what is intended [41], and is unlikely to help the situation.

A variety of explanations for change resistance have been suggested by the research literature. Laumer and Eckhardt [100] review a range of IS-related resistance theories, ranging from perceived threats [99] to power considerations [106] to *status quo* bias [93] and learned helplessness [109]. Many of the theories they discuss have been revealed when studying resistance within organizations, but some theories could well apply to personal security routines too.

Another possible explanation for change resistance is the fact that humans seek to copy their own past behaviors. Ariely and Norton refer to this phenomenon as *self-herding* [8]. This pattern might occur because people have a need for consistency [37], or because changing would require them to admit that the way they have been doing things up to that point was wrong, and this would somehow create a sense of cognitive dissonance [56]. If they were to agree to change the way they do things, this would constitute an admission that their previous routines were sub-optimal and might have led to negative outcomes. Sherman and Cohen [150] explain that people prefer to consider themselves responsible for producing *positive*, rather than *negative*, outcomes. They cite [71, 158, 115] to substantiate this argument. This would mean that if someone were asked to change a personal security routine and told that they had to do this because their existing routine was leading to negative outcomes (insecurity), they might well decline to countenance a change. Changing would constitute an admission of the inadequacy of their existing routines and implied responsibility for potentially negative outcomes, and people might understandably want to avoid this.

It is possible that a number of these factors come into play in this situation, and lead to rejection of switching suggestions, despite any persuasive attempts to describe the merits of the

alternative routine. People might even avoid listening to information that would lead to the uncomfortable feelings of dissonance. Sweeny [157] explains that people do avoid information if such information would require them to change their beliefs, take undesired actions, or be likely to elicit unpleasant emotions. All of these seem to apply to someone suggesting that a well-embedded password creation routine should be replaced.

The situation is probably multi-factorial, and complex, as is most human behavior [130]. It is likely that a range of influences come into play when people reject security advice, and that the reasons differ from person to person and from day to day, depending on a wide range of causatives, ranging from individual to contextual to organizational pressures and characteristics [20]. That being so, we cannot expect any one explanation, and intervention, to “solve” this and remove all resistance. Yet we do not have the luxury of abandoning efforts merely because the situation is so complex. We have to keep trying to pick apart all the factors leading to this resistance and reluctance. Employees can be our strongest defence against hacker attempts, but only if they behave securely. We have to find out how best to encourage and engender this kind of behavior.

In advancing explanations from non-security domains below, we make the assumption that people do indeed know what they ought to be doing (the advised routine) and how to implement it (knowledge & skills). We are not attempting to address a knowledge deficit issue in this discussion.

### 3 Theory Types

Markus and Robey [107] introduce two types of theories that are used when the consequences of organizational change are studied (variance and process). Burton-Jones *et al.* [31] mention both of these and add another: systems. The latter is not as applicable in our context but due consideration of process and variance theories provide a useful perspective to structure our discussion. Variance theory attempts to identify and isolate the impact of predictor variables, and their strengths, on a particular outcome. Such causal identification is generally static and snapshot based. Process theory explains how outcomes develop longitudinally i.e. in discrete and sequential stages.

Variance theories focus on factors that are necessary and sufficient conditions for contributing towards a particular outcome, such as change resistance. Process theories focus on conditions under which outcomes *can* occur, but are not guaranteed to. They focus on particular states or *stages*, and changes of such, in leading to outcomes. Table 1 provides an overview of

the key differences between these two perspectives in terms of studying resistance to change. Figure 1 contrasts the two theories.

	Variance Theory (Imperative) $V_i$	Process Theory (Emergent) $P_i$
Relationship	<b>V1:</b> Cause $\rightarrow$ Effect — Outcome $\{Effect\}$ Cause is <i>necessary and sufficient</i> Effect will <b>invariably</b> occur: — when cause is present Cause <b>explains</b> Effect	<b>P1:</b> Cause $\rightarrow$ Effect; — Outcome $\{Effect, \emptyset\}$ Cause is <i>necessary</i> Effect may not occur — even if cause is present Cause <b>precedes</b> Effect
Amplification	<b>V2:</b> Cause $++$ $\rightarrow$ Effect $++$ Outcome $\{Effect++\}$ <b>More</b> Cause leads to <b>more</b> effect	<b>P2:</b> Cause $++$ $\rightarrow$ Effect; Outcome $\{Effect, \emptyset\}$ Chance and random events play a role
Certainty	<b>V3:</b> Link between Cause & Effect — is <b>certain</b>	<b>P3:</b> Cause makes Effect <b>possible</b>
Trigger	<b>V4:</b> Cause leads to, and <b>engenders</b> , effect	<b>P4:</b> Effects influenced by <b>social phenomena</b>
Focus	<b>V5:</b> <b>Influential</b> variables taking a range of values	<b>P5:</b> <b>Discontinuous</b> and emergent phenomena
Predictability	<b>V6:</b> Outcomes are <i>predictable</i> , based on <b>magnitude of causative variables</b>	<b>P6:</b> Outcomes are <i>predictable</i> from <b>knowledge of process</b>

Legend: causes (  $\rightarrow$  ); precedes (  $\rightarrow$  ); more of (  $++$  ); one of (  $\rightarrow$  ); no effect ( $\emptyset$ )

Table 1: Contrasting Variance and Process Theories (extending Figure 3 from [107])

We cannot hope to review the behavioral change resistance field comprehensively in the related work section of a single paper, so we will provide one variance theory (habit) and one process theory (change readiness). We then introduce the endowment effect, a psychological explanation for change resistance. We will also consider whether it is a variance or process

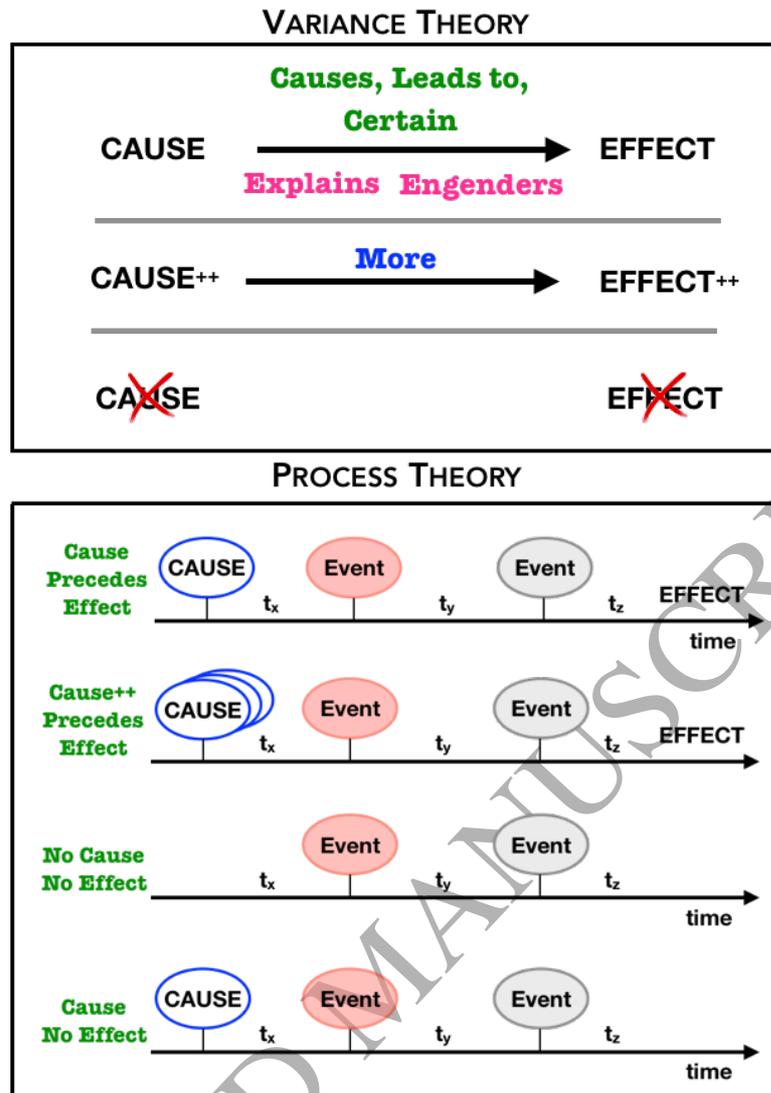


Figure 1: Top: Variance Theory (Imperative); Bottom: Process Theory (Emergent).

theory. In these discussions we will refer to instantiations of the relationships between cause and effect by number  $V_i$  (Variance) and  $P_i$  (Process), as indicated in Table 1.

To investigate the phenomenon of perceived ownership and the endowment effect, as it relates to computer users choosing, then owning, their password creation routine, we must necessarily look at both variance and process theories. Variance models provide insights into the associations that individuals perceive between various perceptions and beliefs, such as perceptions of threats and responses. Process models inform our thinking about how such perceptions and beliefs are formed over the course of time.

### 3.1 Habit (Variance Theory)

Binder and Boldero [20] argue that consideration of habit must be included whenever human behavior is being contemplated. James [84] argued that habits (pre-existing routines) were essential in understanding how humans behave. Aarts *et al.* [1] explain that habits develop to satisfy goals and, over time, become automatic when cued in particular situations (V1). Indeed, Bargh *et al.* [13] found that habits could be cued without people even being aware that a particular habit had been activated (V3). Indeed, Wood and Neal [182] argue that habit associations are constructed slowly as the person engages in the habitual behavior. They are not easily changed, even if current goals are altered.

Duhigg [49] explains that habitual routines are cued by context, and that they lead to a reward. As Aarts suggests, habitual behaviors become ingrained over time as the same cue repeatedly triggers the same routine (V4, V6-considering habit duration as a causative). Pinder *et al.* [131] review behavioral change publications in human-computer interaction research and find that the influence of habit is often neglected. They cite [122] to make the point that “habitual behaviors are the default behavior when people are *unable or unwilling* to make effortful decisions about how to behave” [p.3]. (Emphasis ours)

If we consider that many schools require pupils to start using passwords at a very young age, the pre-existence of password creation habits is likely in adults [104, 171], which would also contribute to their entrenchment and habitual nature (V4, V6).

Habits exhibit the characteristics of a variance theory if we consider the *cause* to be the cue (“create a password”), and the reward to be “ease of password creation”, for example. Significant associations between measures of these constructs imply that the cue is sufficient to trigger activation of the habitual routine (V1). Covariance associations suggest the certain link between cause and effect, once the habit is well established, which is typical of a variance theory (V3, V6).

What many educational efforts do not acknowledge, nor factor into their delivery, is the influence exerted by such habitual pre-existing routines. When people are confronted with a new routine, and asked to switch, those familiar routines (habits) make up a powerful incentive to eschew change. Change being effortful [65], and humans being maximally efficient [52, 190], means that they are not actually making a choice between equivalent options. They are being asked to switch to a much more inefficient option, at least in the short term. Consumer behavior research terms this phenomenon “switching cost.”

Humans are present-focused and more likely to be influenced by present effort than future

benefit [27], making a switch unlikely. This has been termed *psychological distance in the temporal dimension* by the construal-level theory (CLT). It rests on the core tenet that people have direct experience only of the *here and now* and create mental simulations abstracted from this experience, namely “construals”, to represent objects and events that are not directly accessible through senses [61, 54, 162]. Psychological distance has four dimensions: (1) temporal, (2) spatial, (3) social, and (4) hypothetical [12, 162]. The abstractness of these construals depends on their psychological distance from the self, namely the subjective perception that something “takes place further into the future, [...] occurs in a more remote location, [...] happens to people less and less like oneself, and [...] is less likely to occur” [163, p. 84]. Temporal distance refers to the perception that an event occurs at a time near (proximal) vs. far (distal) from the individual (e.g., the near vs. distant past or future). The greater the temporal distance, the higher the construal level used mentally to represent the object or event.

Duhigg [49] advises people to understand their habit loop if they want to break a habit. In particular, they should figure out what the cue is, and what reward the person gains from engaging in the habit, which confirms the influential factors mentioned by V5. For password creation as habit, the cue is clear: a screen asking them to formulate a new password to open an account for some service they want to use. The obvious reward is that they can satisfy their goals as quickly and easily as possible. The less obvious reward is that the password creation habit, if it exists, creates passwords with a measure of automaticity that is attractive to human cognitive misers [175], confirming V4. Habitual password creation routines are thus understandably resistant to change.

### 3.2 Change Readiness (Process Theory)

Norcross *et al.* [123] explain that individuals inhabit particular *stages of change*: (1) pre-contemplation, (2) contemplation, (3) preparation, (4) action and (5) maintenance. The person’s current stage will determine how he or she reacts to a suggestion that a change be made in their existing routine. This kind of staged change readiness is also proposed by [29, 85, 102, 134].

If someone approaches a pre-contemplative person, assuming that he or she is in the contemplation or preparation stages, they are likely to drive individuals in the opposite direction and advice will be rejected [19, 58].

Norcross *et al.* [123] urge anyone wanting individuals to change behavior first to assess the person’s readiness for change, because the most effective persuasive techniques to be used are different for people, depending on their current readiness stage. Yet it is understandable that

security awareness training is not delivered in this way due to the urgency of the issue and the fears around hackers compromising organizational systems. It might seem as if such an approach would be indulgent where such tolerance is simply too risky.

Many people do not understand why people with full knowledge of good practice will not unhesitatingly and willingly adopt it [110]. Their assumption is that “knowledge” as *cause*, leads to strong passwords, as *effect*. Yet the reality demonstrates that this particular cause (knowledge) is not sufficient to lead to the desired effect [11, 105] because the situation is far more complex than a mere lack of knowledge [22]. The same goes for assuming that the existence of a security policy will automatically lead to the desired effect: secure behaviors [181]. Both of these are necessary, but not sufficient, factors.

This confirms P1 and P3. Many organizations will retrain employees when they realise that initial training did not deliver the desired results, and find that more knowledge still does not invariably lead to stronger passwords across the board, demonstrating P2. Tsohou *et al.* [165], for example, find that cognitive and cultural biases shape risk perceptions and security behaviors, confirming the importance of understanding all the factors contributing to the process (P4, P5 and P6).

Change readiness exhibits the characteristics of process theory because people inhabit particular stages, and no amount of training, while necessary and essential, will make any difference to actual behaviors if the person is in a pre-contemplative stage. The transition from one stage to another can happen based on random events or interactions; stages and transitions are part and parcel of the essential process. For example, someone could be completely closed to any idea of change (Pre-Contemplative), but then have a random conversation with a close family member and subsequently be willing to contemplate listening to persuasive arguments (Contemplative) confirming P6. This would explain why, when educational drives often fail to make a difference, and the organization decides that more drives are necessary, these also fail to achieve their aim. More of a particular variable makes no difference when the situation is best described by a process theory (P2).

### 3.3 The Endowment Effect

There is a great deal of evidence to show that people place a higher value on artifacts they own than on those they do not own [2, 34, 59, 86, 101]. This phenomenon, termed “the endowment effect” is evidenced first by a reluctance to exchange owned artifacts for replacements [117]. The second consequence is evidenced by the difference between the amount of money people are

*willing to accept* (WTA) and how much they are *willing to pay* (WTP) for the owned (endowed) artifact, with the former exceeding the latter [2, 117].

This effect is not only triggered by endowed physical artifacts, but also by endowed time and routines [75, 118, 137], which makes it of interest in the password creation context. There is also evidence of the endowment effect being triggered by people self associating themselves with a brand [133]. Even when people were simply asked to associate themselves with a geometric shape did they subsequently associate different rewards with those shapes. It seems worth determining whether people associate their password routines with themselves, given the fact that this self association has proved so powerful in other contexts. If this is the case, it could well trigger an endowment effect as a consequence (P4, P6).

The endowment effect exhibits characteristics of process theory. We know it is triggered when someone feels that they own an artifact (required condition), but it does not infallibly do so (necessary, but not sufficient, to lead to the desired outcome) (P1). Arlen and Tontrup [10] suggest that the endowment effect only triggers when the person owning the endowed artifact has full responsibility for trading it for another. This seems to be another necessary, but not sufficient, condition. This demonstrates the importance of multiple factors preceding a desired outcome effect (P3). In the password field, ensuring that people know how to create strong passwords is also necessary, but not sufficient [66, 69, 70, 88, 114]. Knowledge thus constitutes a third necessary condition that needs to exist, yet there is no evidence that more knowledge invariably leads to more secure behaviors (P2;  $\neg V1$ ).

Two of the pre-existing causes (ownership & responsibility) are either valid or not; there is no way of *varying or amplifying* these conditions. This kind of condition aligns with the tenets of process theory. In the case of the third condition (knowledge), it is clear that having more knowledge does not automatically map to improved password creation routines [74]. This breaks V3 of the variance theory, as enumerated in Table 1. Strahilevitz and Loewenstein [155] explain that the endowment effect increases with the length of time that the endowed artifact has been owned, which also suggests a longitudinal process rather than a single cause with a consequent deterministic effect, confirming P5.

Sometimes people do not feel endowed with an artifact, and so do not over-value it: the endowment effect is not triggered (P1). The variance theory would suggest that ownership will always lead to a feeling of endowment: that the outcome should be both predictable and certain ( $\neg V6$ ). If the endowment effect were explained by variance theory, ownership would be sufficient to trigger the endowment effect ( $\neg V1$ ). This does not occur, which suggests that variance theory does not apply when one considers the endowment effect outcome ( $\neg V1$ ).

Explanations for the endowment effect include:

- a feeling of *ownership* [112, 118]. Such a feeling could lead to a consequent sense of loss aversion [90] at the idea of losing the artifact, or an aversion to the regret that would be felt if a switch were made [155]. Some have suggested that the sunk cost effect comes into play, preventing people from making a change [9, 187].
- individuals feeling a psychological *attachment* to what they own [145, 152] especially if they have owned the artifact for any significant period of time [95, 155]. Chatterjee *et al.* [35] suggest that attachment and ownership interact to evidence as the endowment effect.
- the idea that ownership somehow bolsters *self image* [6, 35, 132], or that people associate the owned artifact with themselves [18, 108]. They might well use it to signal competence [116].

The observable effect of such over-valuing is that the owner will react to a switching suggestion by focusing on the positive aspects of the owned artifact [23, 50, 81, 121, 125], while, at the same time, highlighting the potential negative outcomes of switching [189]. In general, this manifests as change resistance [93] and an apparent discounting of advice [21, 147, 186, 185] when a suggestion of a switch or a swap is made. Consider how this would apply to password creation. Jan comes up with an algorithm to create passwords, and having done so, and liking the positive aspects of using this mechanism, decides to adopt it: a self-endowment as it were. Brehm [26] explains that, having made a choice, Jan is likely to emphasize the positive aspects of the chosen routine, and the negative aspects of the discarded routines. When someone comes along and tries to convince Jan to adopt another password creation mechanism Jan still focuses on the most negative aspect of the new mechanism [23], which might well include the cost, in terms of time and effort, of adopting the new routine.

Consequences of the endowment effect (endowment calculus outcomes) include:

1. the *utility of the artifact being over-estimated*, particularly by subjective *perceptions of risk* [91].

Prior experimental research has investigated the interplay between risk, loss aversion, and endowment effects, but much of that research treats risk and endowment as orthogonal independent variables (e.g., [97, 149]). Moreover, much of that risk-related economic and psychological research employs experimental designs in which subjects participate in

lotteries with known objective probabilities (e.g., outcomes are dependent on dice rolls [7]).

Past endowment research strongly suggests that feelings of endowment are produced "*apparently instantaneously*" [166, p.1041],[89, 128] while risk judgments are "*constructed ... through a combination of a ective and analytic evaluations of risky options*" [57, p.142]. As the product of an extended cognitive process, perceived risk is thus more akin to change willingness than it is to endowment. Accordingly, perceived risk will be conceptualized in our study as an outcome of an endowment calculus.

2. reluctance to adopt new routines (i.e. *change unwillingness*, which is the main outcome of the endowment effect), as revealed in other studies where people decline to make a change because they have already made a choice and want to stick with it [26, 117, 148]. Kahneman *et al.* [90] refer to the endowment effect as the *status quo* bias.
3. the owned artifact will be *over-valued*. For physical artifacts, this is evidenced by the difference between WTA and WTP. For time, it is evidenced by people wanting more payment for their own time spent than they think others should be paid for the same labor taking the same amount of time [75].

### 3.4 Risk

People tend to engage in behaviors based on their perceptions of the risks related to the behavior [142, 183]. Risk perceptions thus play a vital role in predicting whether or not people will engage in precautionary behaviors [24]. A password is intended to prevent people from accessing a resource or service using someone else's identifier. As such, it is essentially a risk management mechanism. Van Schaik *et al.* [170] identified a number of predictors of precautionary cyber security behaviors. Other researchers have carried out similar studies, also identifying particular predictors [67, 79, 164, 103]. These studies confirm a link between risk perception and precautionary behaviors.

Yet other studies have failed to find evidence for this relationship [40, 72, 33]. Hence we considered it appropriate to include a tool to measure risk perception in our model, and to determine the interdependencies between risk perception and the other constructs we are measuring.



































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## Appendix: Endowment Calculus Causative Measures

### Self-Image Test

Terry and Pat are talking about how they create their passwords. Terry’s and Pat’s ways of coming up with new passwords are very different.

Terry says to Pat: "Your way is just plain wrong!"

How do you think Pat reacts? Check as many as apply.

- a) Pat retorts "My way is better than yours."
  - b) Pat says "My way is good enough."
  - c) Pat feels hurt.
  - d) Pat changes the subject.
  - e) Pat ends the conversation and walks away.
  - f) Pat says "Explain why it is wrong."
  - g) Pat says "Tell me more so I can adopt your way."
  - h) None of the above, please explain.
- 

### Over-Valuing Test

Imagine you are opening a new online banking account. You've just come to the part of the process where you're asked to provide a password to protect your account.

Come up with a NEW password in your mind. Don't reuse one of your other passwords.

Now think about the process you've just engaged in to come up with your new password and bear it in mind in answering the next few screens of questions

Imagine the bank really wants to encourage their customers to create stronger passwords. They are thinking of paying people hard cash to do this.

How much should the bank offer their customers (in US dollars) to create a stronger password for their account at this bank?

How much would the bank have to offer YOU personally (in US dollars) to create a stronger

password?

## Measuring Endowment Causatives and Calculus Elements

(Capitalization exactly as used in Survey)

Ownership	<p><b>O1:</b> I feel a high degree of OWNERSHIP of my password creation strategy.</p> <p><b>O2:</b> I feel like I OWN my password creation strategy.</p> <p><b>O3:</b> I feel like the way I create passwords is "MY" password creation strategy.</p>
Attachment	<p><b>A1:</b> My passwords protect my online accounts.</p> <p><b>A2:</b> My passwords EFFECTIVELY protect my accounts.</p> <p><b>A3:</b> I believe my password creation strategy is GOOD ENOUGH for me.</p> <p><b>A4:</b> The passwords I use to protect IMPORTANT accounts are STRONG ENOUGH to resist attempts to breach them.</p>
Perceived Risk	<p><b>P1:</b> My passwords are MORE LIKELY to protect me than passwords created using other routines.</p> <p><b>P2:</b> The passwords I create are BETTER THAN alternatives created using other routines.</p> <p><b>P3:</b> My password creation routine makes it HARDER FOR HACKERS to guess my passwords than other creation routines.</p>
Change Willingness	<p><b>C1:</b> I am <i>willing to consider</i> CHANGING the way I create passwords.</p> <p><b>C2:</b> I <i>plan</i> to CHANGE the way I create my passwords.</p> <p><b>C3:</b> I <i>predict</i> that I will CHANGE the way I create my passwords.</p>

## Biographies

**Karen Renaud** is a Scottish computing Scientist working on all aspects of Human-Centred Security and Privacy. She is Professor of Cyber Security in the Division of Cyber Security at the University of Abertay in Dundee, Scotland. Karen holds a first class Masters degree in Computer Science from the University of South Africa, and a PhD from the University of Glasgow. Karen is particularly interested in deploying behavioural science techniques to improve security behaviours, and in encouraging end-user privacy-preserving behaviours. Her research approach is multi-disciplinary, essentially learning from other, more established, fields and harnessing methods and techniques from other disciplines to understand and influence cyber security behaviours. Karen was one of five UK Cyber Security Fulbright Awardees for 2016/17, hosted at Mississippi State University in Starkville, Mississippi in the USA. She is associate editor for the International Journal of Human Computer Studies, Transactions on Computer Forensics and Security, The Journal of Security and Applications and Information Technology & People.

**Robert F. Otondo** is an Associate Professor of Information Systems at Mississippi State University. He received his Ph.D. in Computer Information Systems at Arizona State University. His research interests center on perceptions and uses of emerging technologies. Dr. Otondo's research has been funded by the National Science Foundation, the Office of Naval Research, the Robert Wood Johnson Foundation, and the FedEx Center for Supply Chain Management at The University of Memphis. His research has been published in the European Journal of Information Systems, MIS Quarterly, Journal of Applied Psychology, Information & Management, Personnel Psychology, Human Relations, Production and Operations Management, and Decision Support Systems.

**Merrill Warkentin** is the James J. Rouse Professor of Information Systems in the College of Business at Mississippi State University. His primary research focus is in behavioral IS security and privacy issues, and has appeared in MIS Quarterly, Journal of MIS, Journal of the AIS, European Journal of Information Systems, Information Systems Journal, Decision Sciences, Information & Management, and others. He was the 2016 AMCIS Program Co-Chair. He holds or has held editorial positions at MIS Quarterly, Information Systems Research, European Journal of Information Systems, Decision Sciences, Information & Management, and the AIS Transactions on Replication Research.