

Cognitive Variability Factors and Passphrase Selection

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Abstract. Specific policies require a secure code to access electronic information. Challenges exist between the established security of passwords. This study explores individualistic behavioral associations of passphrase styles for design insight and recall abilities. Data captured categorical authentication behavior toward external locus of control outcomes. Validation of the survey instrument and memory associative instruments demonstrated the internal and external personality types and cognitive response types to contribute to the systematic quest toward a more secure password. The results of this study were analyzed using a practical evaluation employing a repeated measures structure. This study tested 58 participants who successfully completed a passphrase survey consisting of imposed and user constructed and user imposed and passphrase designs for repeated 1^{st} measures. Although electrophysiological data was collected, it was not analyzed in time for this publication. Results indicate that memory associative factors of cognitively reported $p < 0.05$ for 16 recall items of 75 items of imposed passphrase category types. The locus of control and memory associative variables are significant at the 10^{th} level. Internally controlled participants reported the highest memory recall of imposed and user passphrases. Additionally, the created room objects and animal association passphrases scored the highest among the externally controlled participants. The input of participants was associated with vowels and associated with animals received the least recall. This descriptive study informs passphrase usability identifying cognitive demands that impact memory.

Keywords: Passphrase Authentication, Locus of Control Personality, Cognition, Memorability

1 Introduction

Password objectives spanning more than 40 years have positioned the importance of security and convenience in human computer interaction. Password security continues to dominate the communication in the industry [1]. However, Van Oorschot, and Patrick (2009) question if passwords will be universally used by the year 2019, the secret keyword remains ubiquitous. Varying password selection criteria persists with inconsistent conditions among websites [6] and usability problems continue to exist with passwords [22].

Bonman, Hickey, Van Oorschot, and Stajano (2012) report the difficulty to replace passwords given security and human interaction weaknesses. Usability, dependency, and security advantages framed their focus on evaluation principles. Usability from their study suggest passwords are not expected to be a displaced authentication technology. Therefore, the application of a criteria based methodology furthered their discussion on composition.

Establishing a memorable password is expected to lessen the burden of password creation and repletion. Addas, Thorpe, and Salehi-Abrai (2019) suggest the use of a passphrase is more secure than a password. The results of their study indicated that while users were not constrained to a passphrase format, allowing a free form passphrase suggests to impede the memory advantage of utilizing the Gorilla Passphrase Generator. The Gorilla Passphrase Generator (2019) supports memorability proposed password composition guidelines that suggest to augment memorability and alleviate the difficulty of managing multiple accounts [18].

Grassi, Garcia, and Fenton (2017) define successful digital authentication of a memorized secret to a system when a subscriber provides secret information for a password. The system authenticates that the user and are expected to be successfully recalled. Therefore, similar passwords may be composed and used in other logins. The reuse of password credentials supports memorability by lessening the burden of recall errors. Hickey, Van Oorschot, and Patrick (2009) question if the password reuse challenge is a memorability challenge is off by password reuse. However, security implications and user management of numerous passwords are concerns that impact the progress of enhanced security.

Passphrase structures simulate natural language and therefore suggest to increase memorability [22]. A passphrase memory study devised a way for users to create memorable passphrases using a 4 word passphrase [23]. The results of the study indicated that passphrases composed by the user and are expected to be successfully recalled. Padavan (2019) propose that electing four random words is more secure than a standard password consisting of a combination of characters and numbers. Besides collecting protocols for security from Bonman, Hickey, Van Oorschot, and Stajano (2012) it is noted that all users necessitate security passwords. In fact, passwords are collected by websites to establish a database of user information for other purposes such as marketing purposes and who users are to interact with. Multiple password memorability is shared, and reuse are noted to contribute to this passphrase study. The research examines memorable communication between the user and computer with emphasis on individual selection and recollection of various passphrase types for discrete locus of control personalities and behavioral preferences.

2 Research Design

The passphrase study is designed to expose all university respondents, $N=58$, to all levels of the independent variable reducers that result in regulating variance and alleviating the random assignment of the sample [23]. Repeated measures identify within subject differences in imposed and user constructed passphrases that it is expected to expose to participants that differ among others [8]. Subjects were scheduled for 90 minute appointments at the University of Hawai'i at Mānoa's Hawaii Interdisciplinary Neuroscience Center (HINC) [24]. Participants were recruited from the University of Hawai'i at Mānoa's Qualtrics platform licensed by the University of Hawai'i at Mānoa. Physiological data was collected measuring heart rate, skin conductance, and facial electromyography (EMG) using a BioSemi 32 channel system. The system includes pre-amplifiers, and transducers compiled with the criteria of the International Organization for Standardization that detail laboratory methods for quality management principles [21]. The results from the electrophysiological data collection will be reported in the future.

³ This study intends to predict associations based on theory, clearly defined research questions, hypotheses testing and regression analysis. The survey was processed through a systematic progression of pretesting design principles. Three pilot studies were conducted to validate the survey instrument. The survey instrument was modified for each imposed and user constructed category that are defined by four words containing five letters.

The survey data collected was password secured and manually scored by the researcher. Data was cleaned by comparing the responses to the passphrase requirements and constraints. The survey instrument was evaluated using the IBM SPSS Statistics to be tested using IBM's statistical package for the social sciences (SPSS) that assess the significance and effects of interactions [10]. Data analysis is expected to reveal relationships and patterns to predict the effects of cognition and locus of control personality on passphrase construction and memorability behavior.

3 Passphrase Instruments

Fifty-eight participants were presented with a survey consisting of imposed and user constructed passphrases recall based on four rulesets. Data was collected using existing validated instruments as well as a passphrase survey that was tested using three pilot studies. The survey instrument was modified using the pilot studies. The survey instrument includes the (1966) locus of control (LOC) personality test and Ekstrom, Dermen, and Harman's (1976) memory associative factor cognitive test. During passphrase recall, the Stroop (1935) color word test was randomly distributed throughout the survey to intent immediate revision from working memory. Table 1 illustrates the characteristics of the survey questions.

Table 1. Passphrase Survey Composition

Question Type	Characteristics	Instrument	Usefulness
Self-report	Expression of internal locus of control belief	Test	Indicative of self-knowledge
Closed ended	Identity	Demographic	Indication of self-knowledge
	Multiple choice	LOC Internal External Test	Indicative of self-knowledge
	Memory recall of objects and names	Memory Associative Tests	Indicative of working memory processing
	Physiological	EDA, EKG, fEMG	Psychophysiological information
Open ended	Memory recall of passphrases	Passphrase Recall Test	Indicative of working memory processing
	Construction	Randomized distracter	Indicates in cognitive processing
		Construction Rule Sets	

Source: Adapted from Spiker (2004, p. 255)

3.1 Locus of Control Personality

The passphrase survey was designed using self-reports of the locus control personality test. Locus of control describes a situation to inform individual approaches to one's surroundings [16]. Locus of control is interpreted as internal or external personality. Responses are construed to attribute behavior based on self-perception that are internally determined. Responses on the control or to be controlled by他人 are revealed in the validated generalized reinforcement questions rooted in social, academic, and attitudes of living [24].

⁵ nervous (SNS) and parasympathetic nervous (PNS) systems. Therefore, arousal in electrical signals were captured by the heart rate and skin conductance to indicate homeodynamic effects regulated by the demand of cognitive stimuli [3]. Whereas the corrigator muscle exhibits a non-reflective effect of emotion [25], such activity will be differentially measured.

Variability in physiological responses are anticipated to reveal participant experiences during the processing of passphrase selection and recall. Reactions from the passphrase survey were collected using the electrodermal activity (EDA), heart rate, and facial electromyography (EMG) during the encoding and decoding of passphrases. As of this writing, measurements collected were not analyzed for heart rate pulses, facial electromyography muscle activation, and skin conductance arousal significances.

3.2 Passphrase Survey Items

The passphrase survey consisted of 12 variables measuring 187 items including locus of control, memory associations, and passphrase recall for imposed and created passphrases based on four rulesets shown in Table 2.

Table 2. Passphrase Survey Items

Locus of Control Personality	
Internal Locus of Control	29 items
External Locus of Control	29 items
Memory Associative Factors	
Object Number Associations	15 items
First Name Last Name Associations	15 items
Imposed and User Control Passphrase Rulesets	
Four Words, 8 Characters per Word	32 items
16 Words per Category	32 items
No Vowels	32 items
Four Categories: Food, Nature, Sports, Transportation	32 items
Room Objects	32 items
Animal Associations	32 items
Stroop Word and Color Test	
Randomized distracter used during passphrase recall	98 items
Demographic	
Number of Logins, Age, Gender, Study Focus/Major, Employment Status	5 items

4 Passphrase Survey Descriptive Results

This study consisted of 58 university participants who were exposed to all levels of the independent variables alleviating the random designation of subjects [23]. The repeated measures design categories disclosed differences in passphrase recall and selection of the sample [8]. An anonymous Qualtrics survey was used to present the questionnaire that was accompanied by instructions and examples to facilitate working memory [19].

The locus of control personality scale is indicative of internal traits that have a positive response to perceived regulation of behavior aspects that have been modified and applied to the individual's behavior [15]. Faculty reported that internally controlled personalities are reliant on personal unique characteristics. Externally controlled individuals distinguish events with unpredictability allowing environmental factors to add complexity [15].

Results of the measurements surrounding decision making are implied to indicate personal assessments of the presented stimuli. Responses are expected to amplify behavioral responses to cognitive stressors that impact this design studying execution during passphrase construction and recall.

3.2 The Stroop Effect on Cognitive Load

Passphrase decisions were captured during cognitive load. A rise in passphrases coupled with varying usage and non-standard requirements produce stability difficulties [1]. To interfere with cognitive load, the Stroop test randomly appeared throughout the survey as a distractor mechanism. It prompted the participant to distinguish the word from the ink color. The Stroop effect (1935) is supported by evidence that the correct answer is color. The obstruction interrupts processes allocated to attention and is most effective when cognitive load is high [17].

3.3 Memory Associated Factor-Referenced Cognitive Tests

In cases of working memory recall, this study employed two memory associative factor tests. The assessment of immediate recovery was supported by three pilot tests. Results are expected to lighten the burden of memorability and authentication by examining cognitive load and inform research on passphrases targeted to support recollection. Responses are expected to measure to memorize, recall, and name 15 numbers with objects and first names to last names. Results are expected to measure personal memory to regulate recall abilities. Cognitive processing that effectively organizes associations to arrive at a meaningful command of grouping words advances the ability to manage elements of mental effort attributed to load. Therefore, this study approaches the ability of working memory to serve the diminishing effects over time.

3.4 Passphrase Rulesets

The passphrase survey was designed with four rulesets that required 16 repeated recalls for each category. The imposed passphrases and participant recall responses were used to disclose the number of correct responses classified. Each passphrase contained four words requiring five characters per word. Clear instructions for each question supported participants to create a passphrase, description for each word was defined by the following key words: (a) four words, (b) 8 characters per word, (c) four categories: nature, sports, transportation; (c) select visual objects located in the test room; (d) select words associated with an animal. The same rulesets applied to passphrases that were imposed on the participants.

3.5 Psychophysiological Inferences of Emotion

Each participant was measured for psychophysiological factors including heart rate, skin conductance, and facial electromyography. Electronic sensor capillary signals from the electrodermal activity (EDA), heart rate, and facial electromyography (EMG). Viable occurrences in these physiological states are expected to generate quantifiable dimensions of emotion to passphrase events [7].

Physiological responses demonstrated by reactions to cognitive processing are targeted on behaviors from the autonomic nervous system that traverse to the sympathetic

4.1 Demographics

Figure 1 displays the sample, $N=58$, comprised of subjects who manage an average of 14 active online accounts. Fifty-nine percent are currently employed. The average age is 21 years old.

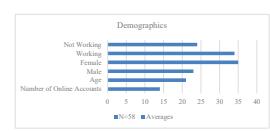


Fig. 1. Demographics

4.2 Locus of Control and Memory Associative Measures

The repeated measures within subjects effects between the memory associative and locus of control variables resulted in the significance of ($p < 0.05$) and the rejection of the null hypothesis, which is below the level of ($p < 0.05$). The partial F ratio reported that 51.5 percent of the sample is attributed to variability. Tukey's test resulted in the significance ($p < 0.05$) in a pairwise comparison. Therefore, the mean difference is significant at the 0.05 level.

4.3 Locus of Control and Memory Associative Factors on Passphrase Types

The sample results indicated that 53 percent of participants were internally controlled while 62 percent scored below the mean for working memory recall of numbers to objects and first names to last names cognitive factor analysis.

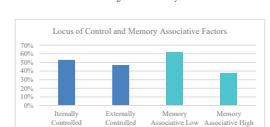


Fig. 2. Locus of Control and Memory Associative Factors Sample

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Specifically, the distribution for internal locus of control resulted in 33 percent who scored below the mean for cognitive processing compared with 21 percent who achieved scores indicative of high memory association ability. The majority of external controlled participants scored low on the factor analysis instrument. The outcomes are shown below in the Figure 3.

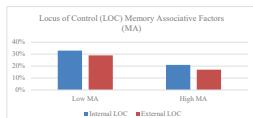


Fig. 3. Locus of Control and Memory Associative Factors Descriptives

4.4 Locus of Control and Passphrase Types

The repeated measures within subjects effects between the locus of control variable and imposed passphrases resulted in the significance of $(p<0)$ and the rejection of the null hypothesis, which is below the level of $(p<.05)$. The partial Eta Squared reported that 38.6 percent of the sample is attributed to variability. In comparison, the locus of control variable and the sample passphrases resulted in the significance of $(p<.036)$ and the rejection of the null hypothesis, which is below the level of $(p<.05)$. The partial Eta Squared reported that 4.40 percent of the sample is attributed to variability.

4.5 Memory Associative Correlation and Passphrase Types

Results displayed in Table 3 depict the memory associative variable was significant with the recall of three forms of imagedaphoresis: (a) four categories ($p = .023$), (b) room objects ($p = .006$), and (c) animal associations ($p = .001$). Therefore, the memory associative variable was significant with the recall of room objects, animal associations, and animal associations, as well as with the created four categories passphrase rule ($p = .003$). The Wilks' Lambda ($\lambda = .051$) statistic identified differences between the four categories and the created four categories passphrase rule. Furthermore, although the memory associative effect on the created passphrase rule sets, the imagedaphoresis rule sets reported a significant effect of $\mu = .002$ with a Partial η^2 ratio of .17.5. The memory associative variable was significant with the created passphrase rule sets, Roy's Largest Root multivariate hypothesis reported significance at $p = .02$. A contrast was conducted to examine the memory associative variable relating to the created four categories passphrase rule set. The F ratio was significant at $p = .003$ for test of significance, which indicated a significant difference between the created four categories passphrase rule set and the created four categories passphrase rule set.

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In contrast to the favored created no vowels passphrase, the imposed no vowel version received the lowest success for both internal and external locus of control respondents. Subsequently, five percent of the internal controlled and two percent of the external controlled sample recalled this passphrase type. The overall approach to recalling a complex passphrase resulted in partial success of the four word passphrase. Individual encoding data will be analyzed in the future.

4 Concluding Remarks

The locus of control construct is perceived to influence decision making during passphrase selection and recall. Behavior moderated by the environment or external forces are predicted to reject unique conditions that are expected to be innate to those encompassing situational command [16]. Consequently, controlled individuals are perceived to embrace passphrase abilities compared with peripheral based contingencies [18]. The created passphrase room objects received the highest recall ability from internally and externally controlled subjects. It can be inferred that visual objects assist in recalling passphrases. Subsequently, internals selected the created no vowels category whereas

passphrases. Subsequently, informants selected the created no vowels category whereas externals preferred the created animal associations.

Unlike the successes from the created rulesets, the imposed no vowel passphrase received the lowest recall from both locus of control personalities. This may be attributed to the difficulty with the four words that require a method for positive encoding. The imposed animal associations followed as the ruleset that was also problematic for memorability.

The physiological data collected will be processed using BISOPAC's AugKnowledge software for electrocardiogram arousal patterns, heart rate frequency patterns, and activation of the facial corrugator muscle. These psychophysiological inferences are then used to predict the likelihood of a subject's ability to remember computer passphrases. Predictors will be analyzed for correlation to cognitive processing to reflect the decision making process of constructing and selecting computer passphrases. The likelihood of a subject's ability to remember computer passphrases is governed by the control features are evident by pulse patterns during cognitive though (1) physiological patterns of cognitive processing and (2) physiological patterns of cognitive processing during computer authentication.

The combination of cognitive processing, locus of control personality, and psychophysiological inferences will be used to gain a better understanding of the processing of working memory recall of computer passphrases. The combination of cognitive processing, locus of control personality, and psychophysiological inferences will be used to gain a better understanding of the recall and behavior of passphrase types that strengthen the support of cognitive processing and behavior of passphrase types that strengthen the support of cognitive processing.

5 Features

Table 3. Correlations for Memory Associative and Passphrase Types (N=58)

	I4C	IRO	IAA	C4C	CRO
Memory Associative (MA)	.023*	.006**	.001**	.003**	
Imposed Four Categories (I4C)					
Imposed Room Objects (IRO)		.033*			
Imposed Animal Associations (IAA)	.046*	.000**		.022*	
Created Four Categories (C4C)					
Created Animal Associations (CAA)				.022*	.003**
Created Room Objects (CRO)					

The majority of respondents were internally controlled. These subjects scored highest in all eight paraphrase types. The imposed paraphrase types are: no vowels (INV), four categories (I4C), room objects (IRO), and animal associations (IAA). The created paraphrase types are: no vowels (CNV), four categories (C4C), room objects (CRO), and animal associations (CAA). As shown in Figure 4, internal control subjects scored the highest recalling the created room objects paraphrase.

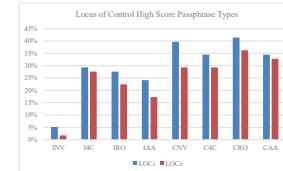


Fig. 4. Locus of Control High Score Passphrase Types

The created no vowels passphrase and created room objects were ranked among the highest recall categories by the internally controlled. Additionally, 69 percent of the sample were effective in creating and recalling a passphrase without vowels. Externally controlled subjects favored to create passphrase based on room objects and animal associations. Respectively, these subjects accounted for 36 percent of the total 78 percent and 33 percent of the total 67 percent.

The imposed four category passphrases followed by imposed room objects received the highest scores for both internal and external controlled subjects. Internals preferred the room objects while externals were inclined to the four categories which accounted for a 28 percent success rate by each group.

References