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Physiological arousal, attentiveness, emotion, and word retrieval in aphasia: Effects and relationships

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Abstract

Purpose: To (a) compare physiological arousal and attentiveness during a confrontational naming task between participants with aphasia and a control group across four conditions that varied according to emotionality of presented stimuli and (b) explore relationships among physiological arousal, attentiveness, perceived arousal, and naming performance. We hypothesized that participants with aphasia would show lower levels of arousal and attentiveness than control participants and that emotional conditions would lead to increased physiological arousal and attentiveness.

Method: Eight participants with aphasia and 15 control participants completed a confrontational naming task under positive, negative, and neutral conditions and rated their perceived arousal after each. Electrophysiological recordings were taken during the entire experiment to obtain measures of heart rate, heart rate variability, and skin conductance. Videos of confrontational naming trials were rated based on visual signs of participant attentiveness during each trial.

Results: Statistically significant group differences were found for heart rate, skin conductance, and attentiveness ratings but no differences were found in these measures among conditions. Correlational analyses revealed statistically significant relationships between attentiveness and response time, heart rate, and naming accuracy. Significant correlations were also found for heart rate and naming accuracy as well as perceived arousal and naming accuracy.

Conclusions: Findings suggest that decreased physiological arousal or attentiveness may contribute to naming deficits for people with aphasia. Assisting people with aphasia to fully attend to and engage in therapy tasks may be important for accurate assessment of language functions and for achieving optimal benefit in treatment.

Introduction

Although aphasia is characterized by language deficits, how people with aphasia perform on language tasks is also impacted by nonlinguistic factors such as attention and emotion (e.g., Harmon et al., 2019, 2022; Murray et al., 1998). Compared with neurologically healthy adult peers, people with aphasia (PWA) often perform worse on standardized attention tests and experience greater decrements to their language performance when attentional demands are high (e.g., Harmon et al., 2019; Murray, 2012; Murray et al., 1998). Emotional processing, on the other hand, which may be a relative strength for PWA (Bloom et al., 1993; Lorch et al., 1998), also has the potential to impact performance on language tasks (e.g., Harmon et al., 2022). Although both attention and emotion have been measured in a variety of ways, physiological measures provide objective information regarding a person's level of arousal at a given time and may serve as proxy for alertness (Laures-Gore et al., 2010) or stress response (Chih et al., 2021). This exploratory study aimed to learn (a) how emotional stimuli affect physiological arousal and attentiveness for PWA compared with neurologically healthy controls (NH) during a confrontational naming task and (b) how changes in physiological arousal relate to naming performance and attentiveness.

Potential Impacts of Emotion on Naming

PWA generally present with spared emotional processing as evidenced by intact emotional expression through facial production, intonation, and use of emotionally laden words (Bloom et al., 1993; Lorch et al., 1998). Previous research indicates that emotional stimuli may impact word retrieval, although evidence specific to aphasia is sparse. Healthy young adults, for example, have been shown to name words with high emotional arousal more slowly than those with low emotional arousal (Blackett et al., 2017; Kuperman et al., 2014) and make decisions about subsequent words more slowly and less accurately when preceded by high emotional arousal vs. low emotional arousal images (Ihssen et al., 2007).

Despite multiple studies investigating the impact of emotional stimuli on various language tasks in aphasia (word comprehension, repetition, discourse), only one to our knowledge (i.e., Harmon et al., 2022) has specifically examined the impact of emotional targets on word retrieval (see Blackett & Harnish, 2022). As a parent study to the current investigation, Harmon and colleagues (2022) asked eight adults with mild to moderate aphasia and 15 NH to retrieve negative, positive, and neutral words with preceding images reinforcing the emotionality of each target. Both groups responded more slowly and less accurately when naming negative words. Both negative and positive conditions were also perceived by participants as more arousing. Physiological data related to these trials, however, were not previously analyzed nor information about how attentive participants were to the task.

Physiological arousal is primarily governed by the autonomic nervous system, which is comprised of two major divisions including the sympathetic and parasympathetic systems. These two systems work together to achieve physiological stability (i.e., homeostasis). The sympathetic system prepares the body for emotionally heightened or attentionally demanding situations by regulating a variety of body functions. Activation of this system, for example, results in increased heart rate (HR), perspiration (i.e., skin conductance [SC]), and hormone release. The parasympathetic nervous system activates a state of rest and helps bring the body back to a balanced, unstressed state following emotional or attentionally demanding situations. Decreased HR and increased heart rate variability (HRV) are example of physiological signs that this system has been activated (McCorry, 2007; Wehrwein et al., 2016). Emotional stimuli have previously been shown to activate the sympathetic system for young adult participants as measured by increased SC and changes in HR (see e.g., Lang et al., 1990) but physiological responses to emotional stimuli for PWA have not previously been investigated.

Physiological Arousal in Aphasia

Previous research has been mixed regarding whether there are general differences in physiological arousal between people with chronic aphasia and controls with some studies showing no differences and others suggesting non-optimal arousal for PWA (e.g., Chih et al., 2021; Laures-Gore et al., 2019; Riley et al., 2019). Studies have also differed in whether they primarily related physiological measures to attention or emotion.

Some studies investigating changes through electrocardiogram (ECG) recordings during a variety of cognitive-linguistic tasks have found no difference in physiological arousal between PWA and NH. For example, Riley and colleagues (2019) measured HR and HRV in 10 PWA compared with 10 control participants. They found that during an oral reading task, HR and HRV were not statistically different between groups. Similarly, Chih and colleagues (2021) found no statistically significant differences between PWA and a control group in relation to HR and respiratory rate during counting and naming tasks.

Conversely, a number of studies using both electrical and hormonal responses have shown lower physiological arousal in PWA than NH. For example, blood pressure and electroencephalographic activity have been shown to be lower for PWA than controls when completing both linguistic and nonlinguistic tasks (Laures et al., 2003; Riley et al., 2019). Relatedly, when completing verbal and spatial working memory tasks or talking about their occupation, a control group was found to increase physiological arousal as measured by HRV or cortisol reactivity as task difficulty or time performing the task increased whereas no change was found for a group of participants with aphasia (Christensen & Wright, 2014; Laures-Gore et al., 2007). Hormonal indicators of arousal as measured by cortisol awakening response have likewise indicated differences between PWA and controls. Cortisol awakening response accounts for the spike in cortisol levels that is typical 30-60 minutes after waking up prior to these levels tapering off throughout the day. This response, which prepares a person for the physical and cognitive demands of the day, was recently found to be absent in PWA (Laures-Gore et al., 2019).

Interpretation of physiological measures in the aphasia literature also varies between primarily indicating attentional responses (e.g., alertness, effort) on one hand to primarily indicating emotional responses (e.g., stress) on the other. In relation to attention, HR and HRV measures have been used as objective markers of cognitive effort and attentional resource allocation (Christensen & Wright, 2014; Riley et al., 2019). In relation to emotion, cortisol reactivity, HR, and respiratory rate have been used as objective markers of participants' stress response—although what were designed and perceived as stressful conditions did not always impact these measures (Chih et al., 2021; Laures-Gore et al., 2007, 2010). For example, Laures-Gore and colleagues (2007) found no relationship between ratings of perceived stress and measures of cortisol for 14 PWA and Chih and colleagues (2021) found significant changes in perceived stress for both PWA and controls as demands associated with a naming task increased but no change in HR. Although reasons for these results remain unclear, previous authors suggest that this finding could relate to speaking tasks generally increasing physiological arousal regardless of difficulty (Chih et al., 2021) or the use of coping resources, which may buffer the suspected physiological response (Laures-Gore et al., 2019). Despite differing across studies, interpretations of physiological arousal as indicating either an attentional or emotional response are not necessarily mutually exclusive. For example, participants with better attentional resource allocation may experience more stress because they can attend to how they are being perceived by a communication partner (Harmon et al., 2020; Laures-Gore et al., 2010).

Purpose of the Present Study

Drawing upon previous interpretations of physiological arousal in PWA, this study explored attention and task performance during confrontational naming trials that occurred across conditions, which varied according to emotionality of the presented stimuli. Specifically, the first aim of the present study was to compare attentiveness and physiological arousal (i.e., HR, HRV, SC) during naming between PWA and NH across four conditions (rest, naming neutral pictures, naming positive pictures, naming negative pictures). Because more studies suggest non-optimal arousal for PWA compared with NH than similar arousal (Christensen & Wright, 2014; Laures et al., 2003; Laures-Gore et al., 2019), we hypothesized that PWA would show lower arousal and attentiveness than control participants. Because emotionally laden images are perceived as more arousing (Harmon et al., 2022) and can impact physiological arousal (Lang et al., 1990), we suspected all participants to show increased physiological arousal when naming both negative and positive compared with neutral pictures.

The second aim of the study was to explore the relationships among physiological arousal, attentiveness, perceived arousal, and naming performance. We hypothesized that higher arousal and attentiveness ratings would relate with shorter response times and better accuracy. On the other hand, like previous studies (Chih et al., 2021; Laures-Gore et al., 2019), we did not expect a correlation between physiological and perceived arousal.

Method

This study was part of a larger project analyzing the effect of emotion on confrontational naming in people with aphasia. The study was approved by the BYU Institutional Review Board and all participants provided informed consent prior to participation.

Participants

Eight PWA and 15 NH who were matched for age ($t[14] = -.300$, $p = .768$), level of education ($t[13] = -1.924$, $p = .077$), and gender were included in the study. These were the same participants as those included in the aphasia and older adult groups of the parent study (see Harmon et al., 2022). For participants with aphasia, the average age was 52 years (*SD* = 14 years; range = 34-76 years) and average years of education was 15 (*SD* = 2). As per inclusion criteria, all PWA demonstrated chronic aphasia (i.e., more than a year post-onset) as the result of a left hemisphere stroke and presented with current word-finding deficits as evidenced by a score of less than 13 on the Boston Naming Test short form (BNT; Kaplan et al., 2001). For control participants, the average age was 53 years (*SD* = 14 years; range = 32-79 years) and average years of education was 17 (*SD* = 2). All participants completed hearing and vision screenings.

Participants with aphasia included six individuals with moderate aphasia (4 Broca's; 1 Wernicke's; 1 anomic) and two with mild anomic aphasia according to the Western Aphasia Battery-revised (WAB-R; Kertesz, 2006). The average WAB-R aphasia quotient score was 71.43 (*SD* = 10.54). Additionally, participants with aphasia completed subtests 6 and 7 of the Test of Everyday Attention (TEA; Robertson et al., 1994) to provide descriptive information regarding selective and divided attention skills. Of the eight PWA, seven reported use of antihypertensive medication, four reported use of anticonvulsant medication, and three reported use of antidepressant medication. We did not obtain physiological measures from one PWA (AE09) who was on corticosteroid medication, but still included her in the study because all other measures were obtained. Control participants reported no history of stroke or other neurologic incident by scoring 0 on the Questionnaire for Verifying Stroke-Free Status (Jones et al., 2001). Participants that were included also reported no clinical diagnosis of depression or bipolar disorder at the time of the study. Of the 15 control participants, five reported use of antihypertensive medication, three reported use of antidepressant medication, and one reported use of anticonvulsant medication. Table 1 shows demographic and test information for the eight participants with aphasia. Table 2 shows demographic information for the 15 control participants.

Procedure

This study was conducted in an ABACA format (return to baseline design). Condition A consisted of neutral stimuli, condition B consisted of positive high arousal stimuli, and condition C consisted of negative high arousal stimuli. The order of conditions C and B were counterbalanced. Appendix A lists the target words for each condition and their associated valence and arousal ratings. Each participant was given a three-minute resting period between conditions to reduce potential carryover effects. During this time, participants were instructed to view a low-arousal, neutral image on the screen. Sessions occurred in a quiet room free from auditory and visual distractions and were audio-video recorded with a Canon Vixia HF R80 or HF R21 camera with a Sony ECM-AW4 microphone. Participants were shown stimulus pictures on a 15-inch MacBook Pro.

Each participant was asked to name black and white pictures using only one word and were instructed to do so as quickly and accurately as possible. Prior to beginning the experimental protocol, participants demonstrated understanding of the task during practice trials. Practice trials were followed by an initial 3-minute resting period after which participants began the first naming condition. During each naming condition, 20 trials were presented as follows: (a) two colored images (taken from the Open Affective Standardized Image Set [Kurdi et al., 2017]) were presented for six seconds each, (b) a 1000 Hz, 500 ms tone signaled, (c) a black and white image (taken from the International Picture Naming Project [Székely et al., 2003] and royalty-free clip art websites) was presented until it was named for up to 30 seconds. Both the colored and black and white images corresponded to the emotional arousal and valence of the designated condition (i.e., positive, negative, or neutral) with the purpose of the colored images being to reinforce the associated emotion. Valence and arousal ratings for black and white target images were obtained from previously reported norms (Warriner et al., 2013) and are presented in Appendix A.

Dependent Variables

Physiological Measures. HR, HRV, and SC were the three physiological measures used in the present study. These were selected to identify autonomic nervous system activity related to emotional reactions and attention with HR and SC primarily indicating sympathetic nervous system activation and HRV primarily indicating parasympathetic nervous system activation (McCorry, 2007). ECG and SC recordings were obtained using the NeXus-10 system. Prior to electrode placement, a sterile alcohol skin swab was used to clean areas on which electrodes would be placed. ECG activity was recorded from three disposable silver-silver chloride (Ag/AgCl) electrodes, which were placed on the undersides of each wrist and the underside of the non-dominant forearm. The sampling rate for ECG recording was 256 samples per second. SC was measured using two Ag/AgCl electrodes, which were placed on the palmar surface of the second and fourth fingertips of the non-dominant hand. The sampling rate for SC recordings, which were obtained as microSiemens, was 32 samples per second. ECG and SC recordings were taken continuously throughout the experiment. Participants were instructed to keep their arms and hands as still as possible with their palms facing upwards to reduce motion artifacts. Mean SC for each condition was calculated using BioTrace+ software. Artifacts in SC data were identified through visual inspection. Inter-beat intervals (IBI) were extracted from ECG recordings and analyzed with Kubios HRV analysis software (Tarvainen et al., 2014). Segments containing artifacts, which were identified automatedly and through visual inspection (including comparison of the ECG signal with excessive movement detected during video recordings of the session) were excluded. Mean HR and the power (%) within the high frequency band (0.15-.4 Hz) of HRV results were derived from ECG data.

Attentiveness Ratings. For this study, a scale was modified which had previously been developed and tested with PWA (see Online supplemental table S1; Riley & Owora, 2020). Videos of confrontational naming trials were rated by the third author and two undergraduate research assistants. These individuals were trained on the rating protocol by discussing several examples as a group. They then rated nine practice trials on which they were required to achieve at least 90% accuracy when compared with the third author's ratings. The rating scale included three levels of attentiveness: 0 = off-task behavior, 1 = partially on-task behavior, and 2 = completely on-task behavior. The rating scale also included a list of extraneous behaviors that qualified as off-task (e.g., fidgeting, yawning, closing eyes, scratching body/face). Ratings were completed for every two-second interval then averaged for each trial. Each of the three raters reanalyzed 11% of trials and showed high intrarater reliability (> 97% agreement). Raters also completed 11% to 14% of the same samples to measure interrater reliability, which was also high (> 87% agreement).

Naming Performance Measures. Naming performance measures included accuracy (% correct per condition) and average response time across items named correct in each condition. Each participant was given up to 30 seconds to respond to the stimulus. If their response matched the target word or a predetermined alternative, it was considered correct. Response time was measured from the offset of the auditory stimulus to the onset of the initial phoneme of the correct response in accordance with Philadelphia Naming Test criteria (Dell et al., 1997).

Perceived Arousal. Immediately after the naming task for each condition, participants completed a Self-Assessment Manikin form (SAM; Bradley & Lang, 1994). The SAM is a visual analogue self-report rating scale used to determine an individual's perceived arousal. Participants were asked to mark the image that matched their arousal on a scale ranging from "relaxed, calm, or unaroused" to "stimulated, excited, or aroused."

Data Analysis

Because of our small sample size and problems with normality, we analyzed physiological data using nonparametric statistics: Mann-Whitney U tests for between group comparisons and Friedman tests for within group comparisons. For Friedman test analyses, we averaged physiological and attentiveness data from all three neutral conditions into a single measure to specify the three conditions of interest: neutral, positive, negative. Physiological data were then represented as a delta score from the initial resting to the respective naming condition. Due to measurement error, HR and HRV data were excluded from analysis for one participant (AE03) and SC data were excluded from another participant (AE05). Correlation analyses were performed using Pearson's R. Analyses were completed using R v. 4.0.2 (R Core Team, 2020). Alpha was set at .05 for all statistical tests.

Results

Findings from the present study showed general differences in physiological arousal and attentiveness between participants with aphasia and a control group that were not impacted significantly by condition (i.e., whether they were naming emotionally laden targets). Some relationships were found between measures of arousal or attentiveness and naming performance. Physiological data for both groups across conditions as well as average attentiveness during naming trials are illustrated in Figure 1. Correlations among all dependent variables are presented in Table 3.

Group and Condition Effects

Differences between PWA and NH were found for two measures of physiological arousal (i.e., HR, SC) as well as attentiveness. Specifically, PWA had a significantly lower heart rate than control participants ($W = 995$, $p = .001$) across conditions. Similarly, PWA showed lower skin conductance across conditions than control participants ($W = 1102$, $p = .005$). The one physiological measure wherein no significant difference between groups was found was HRV ($W = 1604$, $p = .933$). Like HR and SC, attentiveness ratings were lower for PWA than control participants ($W = 560$, $p < .001$).

Friedman tests revealed no statistically significant differences across conditions for either group in relation to HR (aphasia group: $\chi^2 = .33$, $p = .85$; control group: $\chi^2 = .53$, $p = .77$), HRV (aphasia group: $\chi^2 = 1$, $p = .61$; control group: $\chi^2 = .13$, $p = .94$), SC (aphasia group: $\chi^2 = .33$, $p = .85$; control group: $\chi^2 = .93$, $p = .63$), or attentiveness (aphasia group: $\chi^2 = 4.75$, $p = .09$; control group: $\chi^2 = 2.13$, $p = .34$). Group and condition effects related to perceived arousal were reported previously (Harmon et al., 2022). Individual participant responses can be found in Online supplemental data file S2.

Correlational Analysis

Correlational analyses revealed several relationships between attentiveness and confrontational naming performance and one potential relationship between a measure of physiological arousal and performance. Specifically, attentiveness was strongly correlated with both naming accuracy ($r = .69$, $p < .001$) and naming RT ($r = -.66$, $p < .001$) suggesting a relationship between how participants were rated in relation to their attentiveness during the task and how quickly and accurately they performed the task. Upon separating the groups, these correlations remained strong for PWA only (accuracy: $r = .55$, $p < .001$; RT: $r = -.59$, $p < .001$). Additionally, a weak positive correlation was found between HR and naming accuracy ($r = .31$, $p = .002$). Like attentiveness, upon separating the two groups, the correlation was strong for PWA (*r* = .58, *p* < .01) but very weak for NH (*r* = - .14, *p* = .23). Unsurprisingly, a strong negative correlation was also found between accuracy and RT (*r* = - .60, *p* < .001).

In relation to perceived arousal, no correlations were found with any measure of physiological arousal. Perceived arousal was weakly correlated, though, with naming accuracy (*r* = - .28, *p* = .005). There was also a weak correlation between HR and HRV (*r* = - .31, *p* = .002).

Discussion

Nonlinguistic factors such as attention and emotion impact linguistic processing for PWA (Harmon et al., 2022; Murray, 2012). Measures of physiological arousal have been used to investigate these factors by serving as markers of alertness or emotional responses like stress (e.g., Christensen & Wright, 2014; Laures-Gore et al., 2007; Riley et al., 2019). In most instances, there are likely complex interactions among alertness, emotion, and performance on language tasks for PWA, which might impact assessment and intervention. The present exploratory study investigated physiological arousal and attentiveness during a task that is commonly used in clinical work with aphasia (i.e., confrontational naming). Although the positive and negative naming conditions did not impact physiological arousal or attentiveness as expected (Lang et al., 1990), findings suggest that PWA may experience lower arousal and attentiveness during naming than their peers with no aphasia and that this may impact their language performance. Additionally, physiological measures such as HR or ratings of attentiveness could be explored as potential indicators of attention during therapy.

Findings from the present study were consistent with the non-optimal arousal previously found in PWA compared with NH (Christensen & Wright, 2014; Laures et al., 2003; Laures-Gore et al., 2019). This may be the result of decreased attentional capacity and/or resource allocation or greater difficulty with the naming task leading to withdrawal or disengagement. Worse performance than controls on both standardized tests of attention and tasks that require complex attention (Harmon et al., 2019; Murray, 2012) may relate to a dysregulation of the autonomic nervous system (Laures-Gore et al., 2019). Consequently, PWA may struggle to experience heightened physiological arousal and/or attentiveness even when demands are high (Christensen & Wright, 2014; Laures-Gore et al., 2007). Indeed, post-hoc correlations between attentiveness and divided attention skills as measured by subtest 7 of the TEA showed a moderate negative correlation, indicating that better attention as measured by this subtest (lower scores indicate better attention) was associated with higher ratings of attentiveness during the naming task ($r = -.416$, $p = .013$). Interestingly, this subtest was also correlated with changes in HR ($r = -.476$, $p = .016$) and HRV ($r = .493$, $p = .012$), indicating that better scores on the subtest also related to more change from rest to naming on these physiological measures. Another possibility is that the greater challenge of the naming task for PWA compared with controls may have caused PWA to withdraw rather than engage in the task. Previous research recognizes the impact of tasks that provide an optimal challenge for promoting motivation and engagement (Bandura, 1997; Ryan & Deci, 2000). This concept has even been applied to naming intervention in aphasia (Evans et al., 2021).

The lack of a condition effect was contrary to our hypothesis that—as had previously been shown in relation to perceived arousal (Harmon et al., 2022) and might be expected given physiological responses from young adults to emotional images (Lang et al., 1990)—emotionally laden targets would increase physiological arousal and attentiveness. Several explanations are possible. First, participants might have experienced heightened emotional reactions that they were able to regulate using coping strategies (e.g., cognitive reappraisal), which buffered their physiological response (Campbell & Ehlert, 2012; Mauss et al., 2007). This could also explain the lack of correlation between perceived and physiological arousal among all participants, which is generally consistent with previous aphasia-specific research (Chih et al., 2021; Laures-Gore et al., 2019) but different from findings from young adults (Lang et al., 1990). Second, the stimuli used in this study may not have been robust enough to elicit a physiological response or the study may have lacked sufficient power to identify actual changes in physiological arousal. Although emotionally arousing images have previously been shown to elicit a physiological response, this tends to be the case primarily for the most highly arousing images (Choi et al., 2017). Previous aphasia-specific research investigating the effects of emotional stimuli on word-level processing, however, has mostly circumvented images by focusing on word comprehension and repetition tasks (see Blackett & Harnish, 2022). Furthermore, individual differences in what images are deemed highly arousing impact physiological response (Choi et al., 2017; Lang & Bradley, 2007). Future research should continue to investigate the impact of emotionally arousing images in aphasia and consider using personalized targets that elicit emotional responses based on one's own previous experience.

Clinical Implications and Future Direction

Although causality cannot be inferred, and spurious correlations are possible given the small sample size, increased alertness and attentiveness related to fewer errors and faster responses on a confrontational naming task. This relationship could suggest that assisting PWA to fully attend to and engage in therapy tasks may be particularly important for both accurate assessment of language functions and achieving optimal benefit in treatment. One approach to this has been behavioral interventions that target attentional processing in aphasia. Indeed, such intervention studies have shown improved performance on attention tasks (e.g., Murray et al., 2006; Sinotte & Coelho, 2007)—although there is ongoing debate about whether generalized attentional training (i.e., training the attention system using nonlinguistic tasks) or language-specific attentional training (i.e., training the attention system within a linguistic context) is most appropriate for PWA (Lee et al., 2013; Peach et al., 2017). Another possible approach is using physiological measures as biofeedback during therapy to monitor and improve attention (e.g., Loudon et al., 2017). This possibility relates to the relationship found in the present study between HR and attentiveness. If this correlation is confirmed in future research, real-time physiological data could be instrumental in helping clinicians monitor attentiveness during therapy and integrate intervention activities that improve self-monitoring. Although to our knowledge, this has not yet been explored, advancements in mobile technologies and applications as well as ubiquitous mobile device use make this a real clinical possibility. Although it is possible that HR might prove a useful proxy for attentiveness, because attentiveness ratings had stronger and more consistent relationships with naming performance than any of the physiological measures, another option would be to train speech therapists on observable behavioral markers of attentiveness, which could then be used to track attention throughout clinical sessions (see Riley & Owora, 2020 for a similar suggestion). If markers of attentiveness were tracked, tailored solutions could be provided to individual patients through feedback, redirection, activity adjustments, or breaks.

In addition to the small sample size and lack of personalized target images, additional limitations in the present study include the lack of information about some factors that could potentially impact physiological processes such as tobacco or alcohol use and physical exercise, the large proportion of PWA on antihypertensive medications, the greater prevalence of motion artifacts in data from participants with aphasia, and potential bias in attentiveness ratings. Unsurprisingly, all PWA except one were prescribed antihypertensive medications whereas this was the case for only a third of control participants. Because of the potential impacts of these medications on physiological arousal (Nazzaro et al., 1993), it is possible that differences in medication use contributed to significant group effects. Remaining still for valid physiological readings appeared to be more difficult for PWA than NH generally. Although we used a strict systematic process for removing artifacts, it is possible that the greater prevalence of artifacts in the data from PWA might have affected our results. It is also possible that the instruction to remain still for physiological measurement caused participants to repress physical signs of distraction—even when disengaging cognitively. Additionally, although attentiveness ratings were randomized across samples, each individual naming trial was viewed in consecutive two second intervals, which likely allowed raters to easily identify duration and accuracy of responses. While we believe that the interval rating system mitigated problems with bias by helping raters focus on each two second segment regardless of the sample, it is possible that awareness of accuracy, duration, and group may have influenced attentiveness ratings. Future research that uses a similar methodology might consider randomizing each trial segment to reduce the likelihood of such biases.

This exploratory study implicates the importance of considering attentional arousal and attentiveness in the linguistic performance of PWA. Future research should confirm these relationships and determine whether decreased attentiveness indeed causes poorer language performance. Given the clinical implications, future intervention research should investigate whether methods to improve attentiveness and engagement during therapy yields improved language outcomes.

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Data Availability Statement: The dataset used for within group comparisons is included as Online supplemental data file S2. Other datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

References

Bandura, A. (1997). *Self-Efficacy: The Exercise of Control*. W. H. Freeman and Company.

Blackett, D. S., & Harnish, S. M. (2022). A Scoping Review on the Effects of Emotional Stimuli on Language Processing in People With Aphasia. *Journal of Speech, Language, and Hearing Research*, *65*(11), 1–19. https://doi.org/10.1044/2022_jslhr-22-00104

Blackett, D. S., Harnish, S. M., Lundine, J. P., Zezinka, A., & Healy, E. W. (2017). The effect of stimulus valence on lexical retrieval in younger and older adults. *Journal of Speech, Language, and Hearing Research*, *60*(7), 2081–2089. https://doi.org/10.1044/2017_JSLHR-L-16-0268

Bloom, R. L., Borod, J. C., Obler, L. K., & Gerstman, L. J. (1993). Suppression and facilitation of pragmatic performance: Effects of emotional content on discourse following right and left brain damage. *Journal of Speech and Hearing Research*, *36*(6), 1227–1235.

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry*, *25*(1), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

Campbell, J., & Ehlert, U. (2012). Acute psychosocial stress: Does the emotional stress response correspond with physiological responses? *Psychoneuroendocrinology*, *37*(8), 1111–1134. https://doi.org/10.1016/j.psyneuen.2011.12.010

Chih, Y.-C., Tsai, M.-J., Stierwalt, J. A. G., & LaPointe, L. L. (2021). Assessing Physiological Stress Responses to Word Retrieval in Individuals with Aphasia: A Preliminary Study. *Folia Phoniatrica et Logopaedica*, *73*(2), 134–145. https://doi.org/10.1159/000506335

Choi, K. H., Kim, J., Kwon, O. S., Kim, M. J., Ryu, Y. H., & Park, J. E. (2017). Is heart rate variability (HRV) an adequate tool for evaluating human emotions? – A focus on the use of the International Affective Picture System (IAPS). *Psychiatry Research*, *251*, 192–196. https://doi.org/10.1016/j.psychres.2017.02.025

Christensen, S. C., & Wright, H. H. (2014). Quantifying the Effort Individuals With Aphasia Invest in Working Memory Tasks Through Heart Rate Variability. *American Journal of Speech-Langauge Pathology*, *23*(May), 361–371. https://doi.org/10.1044/2014

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review*, *104*(4), 801–838. https://doi.org/10.1037//0033-295X.104.4.801

Evans, W. S., Cavanaugh, R., Quique, Y., Boss, E., Starns, J. J., & Hula, W. D. (2021). *Playing With BEARS: Balancing Effort, Accuracy, and Response Speed in a Semantic Feature Verification Anomia Treatment Game*. https://doi.org/10.23641/asha

Harmon, T. G., Jacks, A., Haley, K. L., & Bailliard, A. (2019). Dual-task effects on story retell for participants with moderate, mild, or no aphasia: Quantitative and qualitative findings. *Journal of Speech, Language, and Hearing Research*, *62*(6), 1890–1905. https://doi.org/10.1044/2019_JSLHR-L-18-0399

Harmon, T. G., Jacks, A., Haley, K. L., & Bailliard, A. (2020). How responsiveness from a communication partner affects story retell in aphasia: Quantitative and qualitative findings. *American Journal of Speech-Language Pathology*, *29*(1), 142–156. https://doi.org/10.1044/2019_AJSLP-19-0091

Harmon, T. G., Neilsen, C., Loveridge, C., & Williams, C. (2022). Effects of positive and negative emotion on picture naming for people with mild to moderate aphasia: A preliminary investigation. *Jouranal of Speech, Language and Hearing Research*, 1–19.

Ihssen, N., Heim, S., & Keil, A. (2007). The costs of emotional attention: Affective processing inhibits subsequent lexico-semantic analysis. *Journal of Cognitive Neuroscience*, *19*(12), 1932–1949. https://doi.org/10.1162/jocn.2007.19.12.1932

Jones, W. J., Williams, L. S., & Meschia, J. F. (2001). Validating the Questionnaire for Verifying Stroke-Free Status (QVSFS) by neurological history and examination. *Stroke*, *32*(10), 2232–2236. https://doi.org/10.1161/hs1001.096191

Kaplan, E., Goodglass, H., & Weintraub, S. (2001). *Boston Naming Test - Second Edition (BNT-2)*. Lippincott Williams & Wilkins.

Kertesz, A. (2006). *Western Aphasia Battery-Revised (WAB-R)*. Pearson. http://www.asha.org/SLP/assessment/Western-Aphasia-Battery-Revised-(WAB-R).htm

Kuperman, V., Estes, Z., Brysbaert, M., & Warriner, A. B. (2014). Emotion and language: Valence and arousal affect word recognition. *Journal of Experimental Psychology: General*, *143*(3), 1065–1081. https://doi.org/10.1037/a0035669

Kurdi, B., Lozano, S., & Banaji, M. R. (2017). Introducing the Open Affective Standardized Image Set (OASIS). *Behavior Research Methods*, *49*(2), 457–470. https://doi.org/10.3758/s13428-016-0715-3

Lang, P., & Bradley, M. M. (2007). The International Affective Picture System (IAPS) in the study of emotion and attention. In *Handbook of emotion elicitation and assessment* (Vol. 29, pp. 70–73).

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, Attention, and the Startle Reflex. *Psychological Review*, *97*(3), 377–395.

Laures, J. S., Odell, K. H., & Coe, C. L. (2003). Arousal and auditory vigilance in individuals with aphasia during a linguistic and nonlinguistic task. *Aphasiology*, *17*(12), 1133–1152. https://doi.org/10.1080/02687030344000436

Laures-Gore, J., Cahana-Amitay, D., & Buchanan, T. W. (2019). Diurnal cortisol dynamics, perceived stress, and language production in aphasia. *Journal of Speech, Language, and Hearing Research*, *62*(5), 1416–1426. https://doi.org/10.1044/2018_JSLHR-L-18-0276

Laures-Gore, J., DuBay, M. F., Duff, M. C., & Buchanan, T. W. (2010). Identifying behavioral measures of stress in individuals with aphasia. *Journal of Speech, Language, and Hearing Research*, *53*(5), 1394–1400. https://doi.org/10.1044/1092-4388(2010/09-0236)

Laures-Gore, J., Heim, C. M., & Hsu, Y.-S. (2007). Assessing cortisol reactivity to a linguistic task as a marker of stress in individuals with left-hemisphere stroke and aphasia. *Journal of Speech Language and Hearing Research*, *50*(2), 493. https://doi.org/10.1044/1092-4388(2007/034)

Lee, J. B., Sohlberg, M. M., Memory, W., & Control, E. (2013). Evaluation of attention training and metacognitive facilitation to improve reading comprehension in Aphasia. *American Journal of Speech-Language Pathology*, *22*(May), 318–334. https://doi.org/10.1044/1058-0360(2013/12-0099)S318

Lorch, M. P., Borod, J. C., & Koff, E. (1998). The role of emotion in the linguistics and pragmatic aspects of aphasic performance. *Journal of Neurolinguistics*, *11*(1–2), 103–118. https://doi.org/10.1016/S0911-6044(98)00008-6

Loudon, G., Zampelis, D., & Deininger, G. (2017). Using real-time biofeedback of heart rate variability measures to track and help improve levels of attention and relaxation. *C and C 2017 - Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition*, 348–355. https://doi.org/10.1145/3059454.3059466

Mauss, I. B., Cook, C. L., Cheng, J. Y. J., & Gross, J. J. (2007). Individual differences in cognitive reappraisal: Experiential and physiological responses to an anger provocation. *International Journal of Psychophysiology*, *66*(2), 116–124. https://doi.org/10.1016/j.ijpsycho.2007.03.017

McCorry, L. K. (2007). Physiology of the Autonomic Nervous System. *American Journal of Pharmaceutical Education*, *71*(4), 1–11.

Murray, L. L. (2012). Attention and other cognitive deficits in aphasia: Presence and relation to language and communication measures. *American Journal of Speech-Language Pathology*, *21*(2), 51–64. https://doi.org/10.1044/1058-0360(2012/11-0067)

Murray, L. L., Holland, A. L., & Beeson, P. M. (1998). Spoken language of individuals with mild fluent aphasia under focused and divided-attention conditions. *Journal of Speech Language and Hearing Research*, *41*(1), 213–227.

Murray, L. L., Keeton, R. J., & Karcher, L. (2006). Treating attention in mild aphasia: Evaluation of attention process training-II. *Journal of Communication DIsorders*, *39*(1), 37–43. https://doi.org/10.1016/j.jcomdis.2005.06.001

Nazzaro, P., Merlo, M., Manzari, M., Cicco, G., & Pirrelli, A. (1993). Stress Response and Antihypertensive Treatment. Drugs, 46(2), 133–141. https://doi.org/10.2165/00003495-199300462-00022

Peach, R. K., Nathan, M. R., & Beck, K. M. (2017). Language-Specific Attention Treatment for Aphasia: Description and Preliminary Findings. *Seminars in Speech and Language*, *38*(1), 5–16. https://doi.org/10.1055/s-0036-1597260

R Core Team. (2020). *R: A language and environment for statistical computing* (4.0.2). R Foundation for Statistical Computing. http://www.r-project.org/

Riley, E. A., & Owora, A. (2020). Relationship Between Physiologically Measured Attention and Behavioral Task Engagement in Persons With Chronic Aphasia. *Journal of Speech, Language, and Hearing Research*, 1–16. https://doi.org/10.1044/2020_jslhr-19-00016

Riley, E. A., Owora, A., McCleary, J., & Anderson, A. (2019). Sleepiness, exertion fatigue, arousal, and vigilant attention in persons with chronic aphasia. *American Journal of Speech-Language Pathology*, 1–18.

Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1994). *The Test of Everyday Attention*. Thames Valley Test Co.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology*, *25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Sinotte, M. P., & Coelho, C. A. (2007). Attention training for reading impairment in mild aphasia: a follow-up study. *NeuroRehabilitation*, *22*(4), 303–310. https://doi.org/10.1080/02687030444000741

Székely, A., D'Amico, S., Devescovi, A., Federmeier, K., Herron, D., Iyer, G., Jacobsen, T., & Bates, E. (2003). Timed picture naming: Extended norms and validation against previous studies. In *Behavior Research Methods, Instruments, and Computers* (Vol. 35, Issue 4, pp. 621–633). https://doi.org/10.3758/BF03195542

Tarvainen, M. P., Niskanen, J.-P., Lipponen, J. A., Ranta-aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV – Heart rate variability analysis software. *Computer Methods and Programs in Biomedicine*, *113*(1), 210–220. https://doi.org/https://doi.org/10.1016/j.cmpb.2013.07.024

Warriner, A. B., Kuperman, V., & Brysbaert, M. (2013). Norms of valence, arousal, and dominance for 13,915 English lemmas. Behavior Research Methods, 45(4), 1191–1207. https://doi.org/10.3758/s13428-012-0314-x

Wehrwein, E. A., Orer, H. S., & Barman, S. M. (2016). Overview of the Anatomy, Physiology, and Pharmacology of the Autonomic Nervous System. *Comprehensive Physiology*, *6*(3), 1239–1278. https://doi.org/10.1002/CPHY.C150037

Appendix A

Target words and their associated valence and arousal ratings across five conditions

Neutral 1			Negative			Neutral 2			Positive			Neutral 3		
Word	V	A	Word	V	A	Word	V	A	Word	V	A	Word	V	A
net	5	3	traffic	2.18	5.25	pen	5.63	2.75	candy	7.27	5.03	tie	5.33	3.1
elbow	5.38	3.2	angry	2.53	6.2	shoe	5.78	2.4	beach	7.21	5.1	pan	5.15	3.05
cane	4.64	3	bomb	2.47	5.71	asparagus	5.43	2.73	fairy	6.71	5.04	moth	4.47	2.55
cup	5.94	2.6	cry	3.22	5.45	foot	4.68	2.77	tiger	6	5.55	accordion	5.26	2.94
tire	4.55	3.09	bee	3.68	5.65	match	5.61	3.05	mermaid	7.05	5.58	nail	4.6	3.05
suit	5.89	3.05	hospital	3.52	5.07	sheep	5.32	2.95	wedding	7.35	5.32	oar	5.15	2.72
nose	5.5	3.1	rat	3.21	5.9	lock	4.56	3	football	6.52	5.65	compass	5.75	2.85
pigeon	5.58	2.95	spider	3.35	6.91	seal	5	2.5	cake	7.58	5.33	pencil	5.65	3.11
apron	5.8	2.9	gun	3.66	7.74	straw	5.89	2.35	dancing	7.27	5.48	cube	4.75	3.09
rice	5.7	3	skunk	3.78	5.81	monk	4.9	2.61	kiss	7.78	6.05	lamp	5.74	2.71
hole	5.28	2.95	bullet	3.45	5.89	beard	5.09	3.18	queen	6.52	5.05	toe	5.24	3.1
dustpan	4.67	2.86	mosquito	3.12	5.17	lung	4.84	2.64	chocolate	7.63	5.14	cow	5.42	2.95
chalk	5	2.9	poison	2.16	6.01	rock	5.72	3.14	gold	7.28	6.35	forehead	5.04	3.14
desk	5.56	2.45	ambulance	3.71	5.33	shirt	5.56	2.3	star	7.47	5.5	box	5.33	2.67
card	5.5	2.67	devil	3.11	5.4	fence	5.05	2.7	leopard	6.43	6.26	stool	4.47	2.39
camel	5.29	3.1	robber	2.9	6.2	jar	5.71	2.77	swimming	7.2	5.13	typewriter	5.44	2.4
newspaper	5.11	2.67	tornado	3.63	7.45	dresser	5.28	2.58	music	7.67	5.57	cross	5.67	3.05
spatula	5.14	2.86	punch	3.27	5.8	clarinet	4.74	3.06	video game	6.3	6.56	envelope	5.95	2.8
nun	5.79	2.43	whip	3.6	5.1	table	5.49	3	breakfast	7.39	5	door	5.43	3.19
chair	5.89	2.86	witch	3.14	5.3	hay	5.41	2.43	money	7.1	6.86	chess	5.05	2.86
M	5.36	2.88		3.18	5.87		5.28	2.75		7.09	5.58		5.24	2.89
(SD)	(0.43)	(0.22)		(0.5)	(0.74)		(0.4)	(0.27)		(0.5)	(0.56)		(0.42)	(0.24)

Note. V = valence; A = arousal. Valence and arousal ratings were obtained from previously reported norms (Warriner et al., 2013). Valence was rated on a scale from 1 (unhappy) to 9 (happy). Arousal was rated on a scale from 1 (calm) to 9 (excited).

Table 1

Participants with Aphasia Demographic and Assessment Information

ID	Sex	Race/Ethnicity	Age (years)	Education (years)	TPO (yy;mm)	WAB-AQ	WAB Type	BNT % Correct	TEA 6	TEA 7
AE01	M	AA/NH	52	19	6;01	81.8	Anomic	80	4.74	9.83
AE03	F	C/NH	64	14	7;07	62	Broca's	27	6.45	4.07
AE04	M	C/NH	76	17	3;01	60.3	Wernicke's	60	6	2.56
AE05	F	C/NH	40	13	1;01	83.4	Anomic	80	3.6	7.3
AE06	M	C/NH	42	16	6;06	85.9	Anomic	73	5.4	10.1
AE08	M	C/NH	58	16	14;10	66	Broca's	27	5.3	13.33
AE09	F	C/NH	48	12	16;04	68.8	Broca's	80	5.1	13
AE10	M	C/NH	34	13	5;11	63.2	Broca's	20	-	-

Note. ID = Participants Identification Number; AA = African American; C = Caucasian; NH = non-Hispanic; TPO = Time Post-onset of aphasia; WAB-AQ = Aphasia Quotient on the Western Aphasia Battery Revised; TEA 6 = Test of Everyday Attention Subtest 6: Telephone search task; TEA 7 = Test of Everyday Attention Subtest 7: Telephone search task while counting; BNT = Boston Naming Test. For TEA subtests, lower scores indicate better attention skills.

Table 2

Demographic information from neurologically healthy control participants

ID	Sex	Race/Ethnicity	Age	Education
C01	F	C/NH	42	16
C02	M	C/NH	61	13
C03	M	C/NH	44	20
C04	M	C/NH	79	20
C05	F	C/NH	42	16
C06	F	AS/NH	35	16
C07	M	C/H	34	NR
C08	M	PI/NH	38	16
C09	M	C/NH	32	18
C10	M	C/NH	48	14
C11	M	C/NH	57	18
C13	M	C/NH	59	18
C15	M	C/NH	48	18
C17	M	C/NH	64	18
C18	M	C/NH	66	16

Note. ID = Participants Identification Number; AA = African American; AS = Asian; PI = Pacific Islander; C = Caucasian; NH = non-Hispanic; H = Hispanic; NR = not reported.

Table 3

Correlations across dependent variables

	HR	HRV	SC	Naming RT	Naming Accuracy	Perceived Arousal	Attentiveness Ratings
HR	1.00	-0.31*	0.19	-0.16	0.31*	-0.10	0.27*
HRV	-	1.00	-0.15	-0.01	0.04	0.16	-0.05
SC	-	-	1.00	-0.17	0.08	0.13	0.07
Naming RT	-	-	-	1.00	-0.60*	0.17	-0.66*
Naming Accuracy	-	-	-	-	1.00	-0.28*	0.69*
Perceived Arousal	-	-	-	-	-	1.00	-0.12
Attentiveness Ratings	-	-	-	-	-	-	1.00

Note. * = $p < .01$; HR = heart rate (beats per minute); HRV = heart rate variability (% power within the high frequency band (0.15-.4 Hz); SC = skin conductance (microSiemens). RT = response time.

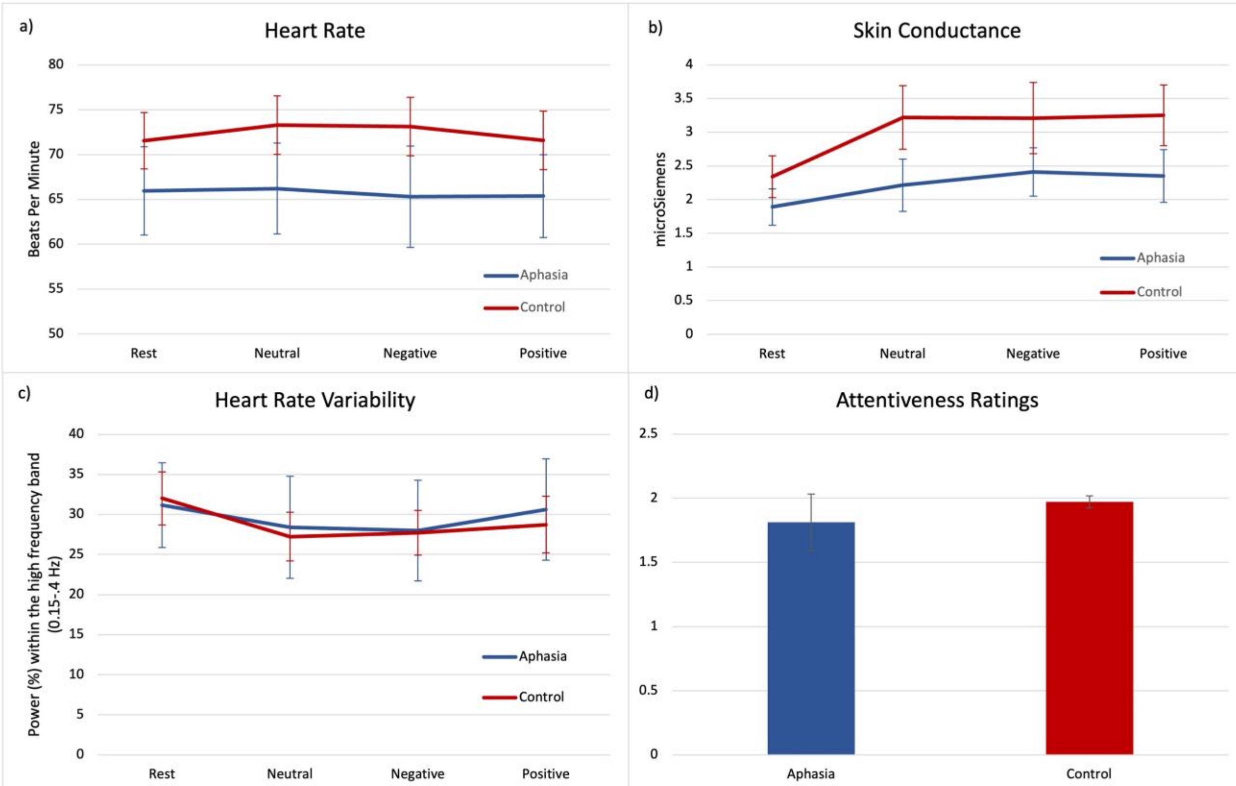

Figure 1. Physiological arousal and attentiveness of participants with aphasia and control participants. (a) Average heart rate of participants across four conditions. (b) Average skin conductance of participants across conditions. (c) Average heart rate variability of participants across conditions. (d) Average attentiveness ratings by group.

Online supplemental table S1. Rating scale for attentiveness.

Rating Scale for Attentiveness

Rating Score	Classification	Definition
2	Completely On-Task Behavior	Eyes and head are directed towards the task for entire interval, attempts verbal response, has no off-task behaviors
1	Partially On-Task Behavior	Eyes and head are directed towards task for part of interval, attempts verbal response, off-task behaviors present during interval
0	Off-Task Behavior	Eyes and head directed away from task for entire interval with no attempts at response, off-task behaviors present during interval

Note. Off-task behaviors include, but are not limited to fidgeting, yawning, closing eyes, scratching body/face. This rating scale was modified from Riley et al. (2020).

Online supplemental data file S2. Long form dataset containing individual data for all dependent variables across three conditions. ID = Participant identification number; NA = no data available for this measure.

https://byu.box.com/s/n9itz0e3ez32rvoj7ty9gyn7tvbk9kwv