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Biometric Analysis of Emotional Responses and Cognitive Effort to Stimuli in Euhydrated versus Hypohydrated States

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ABSTRACT

The purpose of this study was to examine the effects that hydration status, euhydrated versus hypohydrated, has on emotional responses and the intensity of these responses to three separate stimuli of a carbohydrate-electrolyte drink. Six male participants provided informed consent for participation. During a single trial of a walking dehydration exercise in an environmental chamber at 35°C, participants viewed three stimuli, pre and post exercise, consisting of a video commercial, three still images, and live viewing of a carbohydrate-electrolyte drink while reporting perceptual measures. Arousal and feeling states decreased from 3.89 to 2.50 and 3.83 to 2.17 ($p = 0.02$, $p = 0.07$ respectively) while perceptual need for fluid consumption increased from 42.67 to 90.67 ($p = 0.004$). Mental effort measurements, using fixations within the area of interest over time (seconds), increased across the video commercial and the still image viewing, with significance in image 1 and 3 from euhydrated to hypohydrated. Engagement scores increased insignificantly from euhydrated to hypohydrated across all stimuli. An inverse relationship was seen comparing perceptual measures in arousal and feeling states with mental effort and engagement. However, a linear relationship was seen with perceptual need to consume fluids with mental effort and engagement. The video commercial saw the most change, or increase, when compared to the other stimuli measured in both mental effort and engagement scores suggesting that the sensitivity of mental effort and

emotional testing in regard to hypohydration was elicited with video stimuli as compared to other stimuli use.

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INTRODUCTION

Hydration levels are important in affecting overall health and cognitive processes. Improper body water regulation behavior can cause drastic internal physiological changes that can be detrimental to health. Water compromises 75% of human body weight and without water a human can only survive for two to five days (26). Water helps regulate body temperature through sweat secretion and evaporation. Without proper hydration, physical performance can be increasing perception of exercise difficulty and decreasing exercise capability (5). Also, maintaining proper hydration levels help deliver nutrients throughout the body, including to the brain. Without proper hydration, cognitive function decreases (20). This alters visual attention and the ability to fixate on important information.

Additionally, hydration status can affect mood states and the regulation of mood. In psychology, mood can best be defined in literature as a set of feelings varying in intensity and duration, and usually involving more than one emotion (17). Ganio et al. (9) addressed this theory utilizing 26 college aged males, testing the difference of mood states using a profile of mood questionnaires in euhydrated and hypohydrated states, which elicited results of tension and anxiety while hypohydrated versus arousal and vigor while hydrated. In a euhydrated state, mood reports are generally positive, however in hypohydrated states, mood states become more negative and mental capability is reduced due to the physiological impairments seen in a hypohydrated state (8, 20). These impairments, such as low blood pressure and higher heart rates have been suggested as possible explanations for the behavior and mood changes seen in different hydration states.

With the emergence of biometric analysis software, the ability to measure emotional responses through physical attributes is now possible. Previous to this type of technology, self-reported data of mood and perceptions of mood were utilized. Emotion is a three-part system; experience of emotion, reaction to emotion, and response behavior to the emotion. Emotional response varies according to what stimuli is faced (31). When faced with a stimulus, biometric analysis can measure the change in facial expression elucidating the emotional response provoked and the given intensity. Behavioral responses to the given stimuli help emotions to be expressed. Simple examples of these behaviors include frowning when upset or smiling while happy; as such, a connection between mood and emotional response can be seen. A good mood results in positive emotions of happiness or excitement, and a bad mood results in negative emotions such as anger or depression (6, 25, 34). Based on these previous works, it is plausible that biometric technology could be utilized to quantify physical facial expressions, thereby allowing for quantification of altered emotional responses and mood in response to euhydrated and hypohydrated states. An additional emotional measurement tool is the measuring of engagement. The measure of engagement can be quantified through a weighted sum of: brow raise and furrow, nose wrinkle, lip corner depressor, pucker, press, and suck, chin raise, mouth open, and smile. Engagement can be best defined as a measure of facial muscle activation that illustrates the participants' expressiveness. Utilizing biometric analysis these physical emotional responses can be measured, as well as, the intensity of the response.

In congruence with biometric analysis software, eye tracking technology can also be used to measure the focal point of an emotional response. Eye tracking analyzes individual eye movements in terms of fixations and saccades. Fixations refer to the pausing of eye movement over regions of interest, whereas, saccades refer to rapid movements between fixation points (29). Marketing research has also used eye tracking technology with the analyzation of fixation points and time spent on each fixation point (36). This is used to track attention drawing properties such as the logo on a bottle, fonts used for product name, and size of labels (39). With the identification of fixation points, what is being viewed when a response to a stimulus has occurred can be quantified. Fixation time and the number of fixation points can also illustrate mental effort in response to various stimuli (35). Quantifying mental effort can help validate the responses seen when exposed to stimuli by measuring the number of fixation points and the total time spent fixated on each point. This also provides information regarding what triggered the response due to the knowledge of what was being viewed at the exact moment of the response. Changes in fixations that are examined in altered hydration states may prove valuable in assessing various types of stimuli, as well as specific parts of the stimulus that elicits the greatest response.

Despite the emergence of biometric analysis and eye tracking technology in regards to assessment of emotional responses, little research has been done regarding the emotional response variance to stimuli in relationship to hydration status. Emotional response to various stimuli within a single viewing session using biometrical analysis has been done in congruence with Galvanic Skin Response and heart rate (18). However, emotional response differences have not been tested in euhydrated and hypohydrated populations to examine the effects that hydration status has on emotional response. Combining past research methods within dehydration, mood states, emotional responses, and mental effort studies may provide insight into an individual's affinity for fluids and body water regulation. If this is possible, behavioral implications may exist in regard to hydration status.

The purpose of this study is to examine the effects that hydration status, euhydrated versus hypohydrated, has on emotional responses and the intensity of these responses to three separate stimuli of a carbohydrate-electrolyte drink.

REVIEW OF LITERATURE

Hypohydration: Clinically, hypohydration can be defined simply as total body water loss or water reduction. However, this can be broken down into two forms, water deficit or a salt and water deficit (30). A water deficit is known as hypernatremia whereas a salt and water deficit is known as hyponatremia. Typically, hypohydration symptoms are subsided through intravenous solutions that provide adequate solutions that return the body to homeostasis. A vast amount of research has shown that a loss of two percent or more of euhydrated body mass has been quantified to show performance impairments (20), however there are studies that indicate that hypohydration levels of less than two percent can impair performance. A study conducted by Armstrong et al. (2) took eight experienced runners that had to complete three separate runs of 1.5 km, 5.0 km, and 10 km. These runs were completed outside on a 400-meter track. 40 mg of furosemide diuretic was administered five hours prior to running to elicit hypohydration levels. Body mass levels changes of 1.9% (1.5 km), 1.6% (5.0 km), and 2.1% (10 km) were seen post exercise. In comparison to the times ran in a euhydrated state, hypohydration increased run times 3.1% (1.5 km), 6.7% (5.0 km), and 6.3% (10 km). Times were significantly affected in the 5.0 km and the 10.0 km runs with time changes of 1.31 min and 2.62 min respectively. A change of 1.6% body mass resulting from water loss was able to significantly change performance. A hypohydrated state can negatively affect both mood and thirst sensations.

The thirst sensation plays a psychological role in the body's homeostatic regulation regarding internal fluid level (19). Ingesting fluid once the thirst sensation gives rise, can provide intrinsic motivation as evidence of Goulet's meta-analysis. Goulet (11) showed that time trial performance and marathon runners performed better when drinking to quench thirst sensation rather than to replace already lost water. The ability to consume water during exercise has important physiological effects on ability to perform and perceived exertion rates. Water helps regulate core body temperature as well. In a study using nine volunteer subjects that reported physical activity adherence for three to four days a week, Logan-Sprenger et al. (20) performed a crossover study that tested long duration cycling allowing for fluid intake (hydration group) versus no fluid intake (hypohydration group). Each subject performed 120 minutes of cycling at 65% of VO2 Max while either being able to replace water from sweat loss or no water consumption. Environmental conditions were stabilized in the lab. During both trials, the amount of sweat did not differ according to hydration level ($p=0.15$), however, the body mass of the hypohydrated group was significantly lower than the hydrated (fluid intake) group ($p<0.01$). Also, comparing the hydrated group versus the hypohydrated group, there was a proportional relationship between heart rate, core temperature, and rate of perceived exertion. As exercise time increased, so did heart rate, core temperature, and rate of perceived exertion. The hypohydrated group had significantly higher levels in each testing parameter, $p=0.002$ for heart rate, $p=0.003$ for core temperature, and $p=0.001$ for rate of perceived exertion. The rate of perceived exertion differed from a mean of 14.4 in the hypohydrated group versus 12.9 in the hydrated group. This exertion difference increased to a mean of 17.0 and 13.0 respectively by the end of the 120-minute trial. As more body mass was lost (1%, 2%, and 3%), the differences between the groups became more apparent. This indicates that as the severity of hypohydration rises, work becomes more difficult and body temperature regulation decreases. The effects of hypohydration can impair performance and efficiency of exercise. Replacing fluids that are lost is imperative to performing exercise effectively. Hypohydration has shown to affect performance but now it is shown that thirst will further impair performance when compared to euhydrated testing as indicated by Cheung at el. (6) later in this review.

During exercise, it is possible to endure longer bouts of exercise at higher intensities if fluid consumption is allowed. Kamaruddin et al. (17) tested 12 well trained runners in a double blind randomized crossover study with carbohydrate mouth rinsing in euhydrated and hypohydrated states. Each testing session was time to exhaustion running at 70% of VO2 Max and every 15 minutes either 25 milliliters of a carbohydrate solution was rinsed and spit out, or a placebo solution was rinsed and spit out for 10 seconds. Subjects were hypohydrated through exercise prior to the time to exhaustion and were either rehydrated by replacing fluid lost or only ingesting 50 milliliters of water to perform exercise hypohydrated. A passive rest period of two hours was allowed for subject to ingest a given breakfast and either rehydrate or partially hydrate. Following the rest period subjects completed a numeric felt arousal scale numbered one (lowest arousal) through six (highest arousal), as well as, a numeric feeling sale that starts at -5 (feeling very bad) through +5 (feeling very good). These scales were administered every 15 minutes during exercise and immediately post exercise. A linear relationship was seen between exercise time and the felt arousal scale and an inverse relationship was seen when comparing exercise time to the feeling scale. This illustrates the point that the more the subjects lost water, whether starting exercise with proper hydration or not, the arousal increased and positive feelings decreased. However, a significant difference was found when comparing hypohydrated mouth rinse to euhydrated mouth rinse sessions ($p<0.05$), as well as, hypohydrated placebo versus euhydrated placebo ($p<0.05$). This indicates higher arousal in a hypohydrated state amongst the subjects. The rinsing of fluid also increased time to exhaustion in the hypohydrated carbohydrate mouth rinse sessions. With higher arousal and greater time to completion in hypohydration exercise sessions, the suppressant of the thirst mechanism can likely be connected to the motivation to work harder even when feeling worse during exercise.

Mood State and Hypohydration: Water fluctuation in the body is a constant battle due to the various ways the body loses water. Water intake cannot be fulfilled through metabolism or eating foods, it requires the ingestion of water throughout the day. Water loss comes from three main factors: the kidneys through urination, the skin through sweating, and the respiratory system through exhalation. The digestive tract also plays a small role of water loss through fecal matter (13). Fluid intake must match the expulsion of water or a state of hypohydration occurs. Fluid intake comes from drinking fluids such as water or consuming food. The need to drink water is controlled by the thirst sensation that is triggered in a slightly hypohydrated state (7). Constant maintenance of fluid balance is needed to maintain proper hydration status to reduce emotional/mood changes in response to a hypohydrated state. The state of hypohydration occurs when fluid loss exceeds fluid intake.

A water deficit can lead to impaired physiology of the body. Cheung et al. (6) and his study that split participants into four equal groups of varying levels of hydration: euhydrated thirsty and non-thirsty and hypohydrated thirsty and non-thirsty. The subjects were all trained cyclists, measuring heart rate responses and rectal temperature differences between all groups. After baseline measurements, the subjects completed a 90-minute cycle at 50% of VO2, took a 10-minute break then completed a self-paced timed trial of a 20km cycle. Results indicated that heart rates were significantly lower in the hypohydrated groups compared to the euhydrated groups. Rectal temperature was highest in the thirsty hypohydrated group with statistical significance ($p<0.05$). The time trial took longer in both hypohydrated groups due to a significant decline in power output overtime (5). Hydration status effected both heart rates and rectal temperature which lead to decrease power outputs from the muscles used. Within the groups tested, moods of depression and aggravation were seen in those groups that were not able to drink to hydration. Subjects were uneasy and upset while hypohydrated leading to a conclusion that hydration can affect mood state, allowing for emotional responses to occur when presented with a stimulus of a beverage of their choice.

In a similar study conducted by Moyen at el. (23) 119 male and female elite cyclists were recruited to ride a 161-kilometer race. On race day, they completed a thirst sensation, thermal sensation, a urine analysis, and completed a Brunnel Profile of Mood State. These variables were measured one hour before the event, 97-kilometers into the event, and post ride. Thirst, thermal, and pain increased on all levels of the race, which lowered the vigour of the total ride. Throughout the ride, feelings of depression and confusion increased. An inverse relationship between vigor and depression/confusion was seen throughout the 161-kilometer race. As the race progressed, thirst rates increased and hypohydration set in. This connects to the emotions of depression and confusion. Comparing euhydrated to hypohydrated racers, hypohydrated racers had greater emotional responses of depression. Euhydrated racers reported higher levels of vigor, this illustrates hydration status can affect mood state. Moyen also illustrates that heat stress does not influence the mood states reported by the racers due to the same heat exposure amongst all racers. Hydration status can alter mood states while either being properly hydrated or hypohydrated. These results indicate that emotional status can be affected through hydration status; once dehydration sets in an emotional response to a given stimulus that indicates fluid intake should occur.

Symptoms of mild hypohydration can alter moods. Armstrong at el. (3) exercised 25 females in a non hyperthermic environment for three separate eight hour sessions to produce a mild hypohydration state of being with a diuretic (DN) and without a diuretic (DD). Also, a control group of euhydrated participants were used to compare against.

These participants lost 1.36% of body to water loss. Results indicate that the DN and DD groups both elicited lower mood states when compared to the euhydrated control group. The moods reported and experienced by the hypohydrated participants included fatigue and aggravation. Vigor scores lowered significantly creating a negative mood state as compared to the euhydrated group.

Hydration status, more specifically hypohydration, leads to mood/emotional changes within test subjects and even in conditioned populations who are used to being in a hypohydrated state. Simply restricting fluid intake can lower the emotional state of individuals, in contrast, allowing for fluid consumption after excess work can elicit a shift to a positive emotional state (11, 24). These altered emotional states are triggered by the lack of water in the body, which alters physiological processes causing irritability, depression, and fatigue. However, proper hydration leads to emotional responses of happiness, joy, and vigor. These emotions are seen in both, active and non-active populations. Euhydrated states produce positive emotional states unless acted upon by outside stimuli.

Emotional Response and Biometrics: An emotion can be defined as an episode of interrelated, synchronized changes in the states of all or most of the five subsystems states in response to the evaluation of a stimulus, external or internal, event relevant to the major concern of the person (27). Emotions are a way to read people without even saying a word. These biomarkers speak thousands of words with just the reading of the face. Emotions change frequently and rapidly to all stimuli faced throughout any given day. Absolute conscience of the stimulus is not needed to induce an emotional response to the event (12). Psychologist Dr. Hockenbury (13), found that humans can respond to stimuli without full awareness due to fast reaction times becoming almost autonomic. The fast pace of life has adapted humans to react quickly and unconscientiously to stimuli. The stimulus experienced conducts the given emotion seen in response. Behavioral responses to the given stimuli help emotions to be expressed and read allowing others to read emotions of other people. Simple examples of these behaviors include frowning when upset or smiling while happy.

In advancements in technology facial recognition software has become redundant in most devices. The human face and facial features have been studied for years (23). With the vast knowledge collected about facial features, biometric analysis has been utilized to distinguish one person from another. Analyzing facial features can indicate what the person is thinking and/or feeling at that given moment. This is a key feature in determining emotions expressed in response to a given stimulus, as well as, providing information on marketing products. Viejo at el. conducted a study using six separate beer samples and a bio-sensory application on an android tablet to record facial feature changes while sampling the different beers. The videos were then analyzed through Affectivia software. Emotional responses came from both subconscious and conscience facial movements tracked by the biometric. These six samples of beer were measured for sugar content, bitterness, color, fermentation, viscosity, density, pH, and acidity. The 61 participants sampled all six beers. After sampling the six different beers statistical significance shows a correlation between higher sugar content and acidity with positive emotional responses such as joy and excitement. Consumers preferred the high sugar and acidity content that were within the six samples when compared to lower levels of sugar content. Conversely, higher alcohol content and bitterness elicited more negative responses such as agitation and annoyance. With the biometric software analyzing the responses to the beer consumption and illustrating which beer is more accepted to the public gives the company's consumer preferences. This could be used as a great marketing tool due to the non-invasive mode of analyzing responses to consumption.

Emotion is a three-part system; experience of emotion, reaction to emotion, and response behavior to the emotion. Marsi et al. (21) analyzed emotional response to multiple stimuli using the iMotions biometric software. These seven stimuli included five separate pictures and two varying length videos. The pictures include a grasshopper in the mouth of a human, factories polluting the environment, a homeless child sitting in the street with a toy, a poor child looking for food in the trash, and a laughing infant with eyelashes for eyebrows. The videos include sharks eating and attacking humans for one minute four seconds and two friends stabbing and killing their third friend for one minute 48 seconds. Time exposure to video stimuli has been to shown to elicit strong emotional responses in clips averaging 1.5 to 3 minutes in length. As video clip times increase attention begins to wander and emotional responses disappear (11). These stimuli were measured for multiple emotional responses such as disgust, contempt, fear, surprise, sadness, anger, joy, and a baseline of no emotion. In conjunction with a Galvanic Skin Response and heart rate, the iMotions software could analyze emotional responses from the videos gathered and facial feature expressions. Baseline measurements were compared to post stimuli responses to determine what emotions were elicited. The two males and two females tested reported individual results when the stimulus were introduced, even while trying to keep a neutral face position. A majority of time results indicated a neutral emotional position amongst all stimuli presented, while sadness, anger, surprise and contempt were the most intense emotions recorded amongst the subjects. Subjects peaked the emotion then returned back to the neutral facial position. While each participant reacted to each stimulus in some degree as shown through the iMotions software analysis, the emotional reactions were similar amongst the subjects. The variance was elicited through intensity of response. This iMotions software allows the reading of emotional responses to any given stimulus, making it beneficial in multiple facets such as marketing, criminal investigations, and detection of hydration status.

Biometric analysis allows identification using unique characteristics, both physical and behavioral, that everyone contains. When introduced to an outside stimulus, voluntary and involuntary reactions occur both physically and behaviorally (6). The seven basic emotions that the iMotions software can measure are: joy, sadness, anger, surprise, fear, disgust, contempt. iMotions software can tell us multiple emotional responses with one given stimulus as well as how long that response is elicited all measuring facial changes. Lei et al. (19) analyzed the responses to stimuli using iMotions software similarly to Marsi. However, Lei used eight separate videos. Both studies kept environmental conditions constant for all participants. Lei measured the responses of eleven participants when viewing: Stimulus 1, Mother shaming her daughter for being obese, Stimulus 2, Pipe cannon bursting suddenly, Stimulus 3, Man punching a kangaroo, Stimulus 4, Commercial about a deaf and mute father giving up his life for his suicidal daughter, Stimulus 5, Conceited, self-righteous teenage girl, Stimulus 6, Time lapse of a rotting watermelon, Stimulus 7, A worker alone in an office takes a strangely accurate Internet quiz, Stimulus 8, Twin baby girls showing affection to each other. Results show that all participants had individualized results. Although, contempt, fear, sadness, disgust, joy, anger, and surprise were all shown in each participant throughout testing. Surprise, anger and joy were the highest reported emotions amongst the subjects when exposed to the stimulus set at 36.76%, 35.39%, and 28.38% respectively. However, results of the concluding emotional responses were conclusive when comparing to Galvanic Skin Response and heart rate changes. This validates the iMotions emotional response results to the given stimulus. Using the biometric analysis allows for proper emotional response readings and to have accuracy when concluding emotional responses. Using biometric analysis to analyze emotional responses through changes in facial features is beneficial in multiple facets. When compounding research methods with dehydration studies because mood states are changed due to hypohydration, biometric analysis can help predict dehydration status before exercise even starts. After providing baseline data of a euhydrated state, hypohydration can be seen through facial recognition software such as iMotions based off changes in facial features. Future research should analyze the effect of stimuli introduced to hypohydrated subjects to present what emotional responses are given during a hypohydrated state to predict what would promote proper hydration.

Eye Tracking: In congruence with biometrical analysis, eye tracking technology has surfaced to administer a role in visual and cognitive processes. This tool has been used to analyze behaviors in domains such as image scanning, arithmetic problems, and reading. Marketing research has also used eye tracking technology with the analyzation of fixation points and time spent on each fixation point (36). This is used to track attention drawing properties such as the logo on a bottle, fonts used for product name, and size of labels (39). Eye tracking analyzes the eye movements in terms of fixations and saccades. Fixations refer to the pausing of eye movement over regions of interest, whereas, saccades refer to rapid movements between fixation points (29).

A study conducted by Chen et al. (5) used 12 male basketball participants that watched 15 second video clips for basketball training. The participants had to memorize the players positions and draw them onto a blank basketball court page. Also, during the video the participants had to complete six subtasks that measured mental effort being used during the video. Each participant completed eight separate sessions on different days. Results indicate that fixation time and fixation rate were elevated when tasks were more difficult ($p=0.0096$). Fixation indicates time spent analyzing a specific area meaning that increased fixation time in harder tasks indicates higher mental effort. This linear result indicates that more difficult tasks require higher mental higher. The greater the stimulus is the more mental effort that is needed to comprehend the situation. Also, the longer the fixation time is seen because more time is needed to comprehend the situation. Within this study player position memorization was a part of the methods, this measurement required saccade speed to analyze all positions within the short time. Saccade measures the eye tracking from one fixation point to another. Easier tasks require less bouncing from one fixation point to another, and the harder the task the less bouncing seen. Therefore, the greater the mental effort needed to complete a task the less saccade and more fixation will be seen in analyzation. These differences show that the more stimuli introduced during a short time span the higher the mental effort needed to analyze what is being introduced.

With the connection seen above, the less intense the stimulus is the less mental effort is needed to analyze the situations. With the less intense stimulus, fixation times can increase to allow for more time spent on what is important. Also, fixation rate time can increase due to the small amount of fixation points. The more fixation points introduced the higher the mental effort becomes. Saccade rates are reduced in simple stimuli which reduces mental effort because there is less need to switch from one fixation to another. Therefore, the higher the saccade rate the higher the mental effort is. Mental effort has shown to be correlated with task difficulty (35). The degree of effort expended relies on how difficult a task is to perform. These tasks may be reported as difficult due to an inability to complete them because of limited resources. Also, a certain degree of cognitive control is needed to complete each task that is non-automatic. If the level of control is not attainable by a participant or subject then it is likely to be graded as difficult. In response to stimuli two ways of cognitive effort may be used: model free or model based. Model free refers to the simple acknowledgment of outcomes, whereas, model based effort analyzes the stimulus with outcome variables and sequences needed to accomplish the desired outcome. The degree of mental effort put into each situation based on these theories is individualized but can be linked to education level.

METHODS

Participants

College aged males participated in a single session trial of euhydration and hypohydration states. Participants were physically active which is defined by exercising for at least 30 minutes a day, three times a week, for the past three months (12 weeks). Participants were not be included if they have been previously diagnosed with any chronic illnesses or cardiovascular diseases. Each participant underwent a familiarization session regarding equipment and individuals they worked with.

Familiarization

During the familiarization session, each participant had their informed consent read to them and were asked to sign the form in acknowledgement prior to participation. The American Heart Association/ American College of Sports Medicine health questionnaire was used to detect any contraindications to subject participation. Participants were asked to keep a written log of how much water they ingested for the 24 hours prior to their trial to help ensure euhydration. Additionally, participants were instructed to consume at least 500 ml of water at 2100 hours the evening before the trial to help ensure euhydration status. Participants were asked to abstain from consuming alcohol, caffeine, energy drinks, or any other supplements 24 hours prior to their trial, and strenuous exercise for a full 24 hours and the day of the trial. The participants height and weight was measured using a Detecto scale (Webb City, MO). Body fat percentage was estimated using the three-site skinfold caliper method using Lang calipers (Cambridge, MD) (chest, abdomen, and thigh) following the implemented protocol by the American College of Sports Medicine. The participants then viewed the stimuli that were used during testing to minimize any impact of a learned effect or ordering effects amongst trials. Each participant completed the Bruce Protocol treadmill (Woodway, Weil am Rheine, Germany) test to volitional failure to predict maximal oxygen consumption (VO_{2max}) using the regression equation (VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) = 58.443 - (0.215 · age) - (0.632 · Body Mass Index) - (68.639 · grade) + (1.579 · time). Predicted VO_{2max} was established to standardize workloads across participants that elicit a work rate of VO_2 reserve of 40%.

Stimuli

This experiment uses three separate stimuli in a randomized order between participants (ABC, ACB, BAC, BCA, CAB, CBA). The order determined through randomizatiset the order for stimulus viewing order for both euhydration and hypohydration states. The stimuli include: a readily available commercial video, a still image presentation of 3 separate images in which viewing of the image will last three seconds with a 10 second grey screen shown in-between each image for participants to return to their baseline emotional state, and an in person viewing of a bottle full of the preferred drink that will be placed in front of them. Each stimulus had an area of interest (AOI) utilized for mental effort measurements. The AOI was set on all beverage consumption scenes during the video commercial and encompassed the entire ECHO bottle for the still images. An AOI for the live viewing was unable to be obtained, as the cup containing the beverage blocked the face of the participant, making data collection impossible.

Intervention

Set-Up: The iMotions software (Boston, MA) was installed onto a laptop along with the Tobii X-260 eye-tracker (Boston, MA). The laptop was setup in an isolated room with consistent lighting and no outside stimuli are observable.

Prior to testing, participants were asked to report perceptual measures that consisted of the Feeling Scale (FS) and the Felt Arousal Scale (FAS) to create a baseline prior to testing to account for entry level mood states that may alter measured responses with the technology utilized, along with any variation between water consumption logs collected during the familiarization period. FS is a single-item, 11-point measure designed to assess affective valence (i.e. positive or negative feeling states). The FS ranges from -5 (very bad) to +5 (very good), with an anchor at zero (neutral). FAS is a single-item, 6-point measured designed to measure intensity of perceived activation (i.e. arousal). The FAS ranges from 1 (low arousal) to 6 (high arousal). 100 mm visual analog scale (VAS) is used to examine subjects' desire to consume fluid. Subjects were asked to draw a vertical line on a 100-mm horizontal line which will be anchored by likert terms stating, “no desire for consumption” and” great desire for consumption.”

Euhydration Testing: At the start of the intervention, participants arrived in a euhydrated state. They were escorted to the isolated room where the laptop with biometrical analysis and eye tracking was set up. A video camera was placed directly in front of them allowing for symmetrical viewing of the face. The eye tracking device was then placed on the participant to monitor responses that were elicited in regard to eye movement. To record baseline emotion, each participant viewed a grey screen for 10 seconds before and after each stimulus. Measurements of emotion during stimuli exposure was analyzed by comparing values obtained during the grey screen viewing.

Water Extraction: Upon completion of Euhydration responses to stimuli, participants performed an active dehydration exercise bout in an environmentally controlled room at 35℃. Core temperatures were measured throughout the protocol using rectal thermocouples (Physitemp Inst., Cliffton N.J.). A core body temperature reading of above 38.7℃ was set as termination criteria and immediate removal from the environmental chamber for safety precautions. The participants heart rates were monitored using a Polar chest strap and watch (Polar Accurex II, Finland) throughout the protocol. Core body temperature (Isothermex) and heart rate were recorded in five minute increments.

During the dehydration exercise, participants were given a range of speeds and grades that they can walk on a Woodway treadmill (Woodway, Weil am Rheine, Germany) that will elicit a work rate of 38% and 42% of their VO_2. Dry body weight was measured every 30 minutes in order to achieve two percent of initial body weight water loss. Once two percent of water loss is achieved, participants rested until sweat profusion ceased and then were taken back to the isolated room to view the stimuli in the same order as previously seen.

Hypohydrated Testing: Following hypohydration, fluids were kept from the participants; ingestion of water, or any other liquid, was not allowed. The participants sat in the isolated room and were administered the FAS and FS scales once again to account for changes in perceived mood state. The participants were also be reintroduced to the stimuli in the same order completed in the euhydration testing. The protocol for stimulus introduction and emotional response stimulation measurements will be the same as in the euhydration testing.

Statistical Analysis

The statistical analysis performed was a paired samples T-test, comparing time (euhydrated and hypohydrated) to the stimuli, as well as, discerning differences from pre to post within mental effort and engagement. A paired samples T-test was also used to compare time to the perceptual measures, VAS, FS, and FAS.

RESULTS

All 6 participants completed the active walking dehydration trial. Trials (120 ± 14.49 minutes) were conducted in mean dry temperature of 35.59 ± 0.22°C at mean humidity levels of 22 ± 3%. Means and standard deviations of participants' physical characteristics and changes of physiological variables are shown in Table 1.

During the exercise trial, participants lost an average of 1366.67 ± 167.41 mL of sweat (2.02 ± 0.09%).

Perceptual Score: Means and standard deviations of participants' perceptual scores at pre and post exercise trials, as well as, during the trials are shown in Table 2.

There were significant differences in FAS and VAS pre to post exercise trial ($p = 0.039$, 0.004 respectively). There was no significant difference in FS between pre and post exercise trial ($p = 0.066$). In the exercise trial, pre to post measurement, the FAS scores decreased with significance from 3.89 ± 1.17 to 2.5 ± 0.84 and the desire to consume fluid (100 mm scale) increased from 42.67 ± 25.60 to 90.67 ± 6.59. FS scores decreased from 3.83 ± 1.60 to 2.17 ± 2.23 without significance.

Mental Effort: Mean and standard deviation scores for video commercial, each still image and gray baseline screen pre and post exercise trial are shown in Table 3. While live viewing stimulus was also proposed, mental effort was not able to be quantified due to the inability to have the beverage in the screen as it blocked facial feature changes. Within all participants images 1 and 3 saw significant changes in mental effort ($p = 0.002$, $p = 0.017$ respectively, but no significant change was elicited in image 2. All three electrolyte beverage images increased in mental effort from 9.04 ± 4.89, 14.88 ± 14.76, 9.51 ± 6.90, 13.47 ± 9.85, 9.06 ± 4.58, 15.31 ± 10.18, respectively. Gray screen image fixation rates for screens 1,2,and 3 also increased slightly in mental effort (5.86 ± 4.18, 9.26 ± 6.37, 9.33 ± 6.19, 13.79 ± 12.93, 12.41 ± 8.85, 12.69± 11.94 respectively) with significance in the 3rd gray screen and no significance in gray screen 1 and 2 ($p = 0.049$, 0.398, 0.273 respectively).

Biometric Analysis: Mean and standard deviation scores for engagement during video commercial, each still image screen, and live viewing pre and post exercise trial are shown in Table 4. Within all participants across each stimuli, no significance was seen in regard to engagement. Little engagement was elicited in stimulus viewing both pre and post exercise. All stimuli except image 1 saw increases in engagement as seen in Table 4. Baseline gray screens elicited zero engagement responses.

DISCUSSION

The purpose of this study was to examine the effects that hydration status, euhydrated versus hypohydrated, has on emotional responses and mental effort, in regards to the intensity of these responses amongst the three separate stimuli of a carbohydrate-electrolyte drink. It is known that hypohydration causes many physiological responses and decreases cognitive function (6, 11, 20). To our knowledge, we are one of the first to examine the emotional difference between hydration states using biometrical analysis software across several stimuli and to measure the intensity of these responses in congruence with mental effort. Past literature has shown a relationship between hypohydration and reported perceptual negative emotional responses (6, 9, 20). Therefore, it was hypothesized that biometrical (iMotions) software would be able to illustrate emotional responses represented by engagement produced and the intensity of these responses in different hydration states.

Changes in Perceptual Scores: The FAS and FS perceptual scales decreased from a euhydrated to hypohydrated state, showing a negative correlation in mood in a hypohydrated state. The decrease in arousal were significant, whereas, the decrease in feeling states were not. This significant decrease in arousal illustrates a lower excitement level amongst the participants, which should elicit a stronger negative emotional response similar to ultra-endurance cyclists that performed mood state profiles pre and post ride and found similar results eliciting lower arousal with no change in task completion (23). VAS scores increased from euhydrated to hypohydrated states illustrating the desire to consume fluids significantly increasing while hypohydrated. This solidifies that water loss occurring during the trial elicited perceived increases in fluid affinity which in theory would elicit a more intense emotional response when viewing the stimuli.

Changes in Mental Effort: Amongst all participants' (n=6) mental effort increased across the stimuli produced with significant change in images 1 and 3. This change is a result of an increase in fixation points from euhydrated to hypohydrated states with time spent viewing the stimuli remaining constant. These data reveal that participants increased the total number of fixations over time, increasing their mental effort. While watching the readily available commercial of beverage consumption, the greatest changes in mental effort were seen. The ability to fixate on the beverage consumption AOI increased in the hypohydrated state. Also, as shown in Figure 3 fixation locations differed from pre to post trial from the liquid of the bottle to the logo of the bottle. Past literature in marketing research indicates the logo is designed to attract fixations and does so more readily in a hypohydrated state. This change shows that the logo may have more of an effect on attracting the mental effort due to the knowledge of how the commercially available beverage is meant for "refueling" when in a hypohydrated state (36,39). The commercially available beverage could have illustrated an increase in interest in a hypohydrated state, rather than additional mental effort. The logo and brand of beverage could have increased the interest of the participants due to the increase in perceived need to consume fluids. Therefore, the results of increased mental effort could be a product of increased interest in consuming the beverage in a hypohydrated state. Amongst the baseline gray screens, little increase in mental effort was observed. However, even in the gray screens, that were meant to reset emotions and mental effort to baseline, fixation points slightly increased illustrating a slight change in mental effort used during gray screen baseline images. Based on this data, we can conclude that hypohydration does not hinder the ability to increase mental effort when a stimulus is present, whether that stimulus be in a video commercial format, a still image format, or a normal computer screen. However, the still image was statistically significant at producing increased mental effort, which suggests that it was the more effective stimulus at eliciting these results.

Biometrical Analysis: Hydration status, euhydrated versus hypohydrated, effected engagement scores as measured by biomertrical analysis. Engagement is best defined as involvement or investment with a specific task. Across the stimuli used in this study, changes in engagement scores were seen using iMotions, in congruence with significant changes in arousal were seen in perceptual scores and the desire to consume fluids increased significantly from euhydration to hypohydration. However, these changes were relatively low in regard to the 0-100 scale they are measured upon. This was also found in a study conducted upon healthy young female endurance cyclists, as hypohydration set in vigor or arousal decreased with an increase in thirst sensations while task completion times did not change (3,23).

Engagement scores increased across all stimuli except image 1 and baseline gray screens from euhydrated to hypohydrated states. This illustrates that even in a hypohydrated state, participants were able to engage and show involvement while viewing the stimuli. The live viewing saw an increase greater than the images viewed, but the video commercial engagement scores were the greatest. While watching the commercial, engagement scores increased with the most intensity amongst the AOI's measured. This directly trends with the mental effort findings, in that both mental effort and engagement increased with the most intensity in the commercial viewing.

CONCLUSION

Perceptually, arousal and feeling states decreased, whereas, mental effort and engagement levels increased from a euhydrated to a hypohydrated state. Armstrong et al. (3) found that hypohydration acquired from exercise affects mood states. Therefore, a decrease in mood state represented by decreased arousal and feeling states did not negatively affect mental effort or engagement. Cognitive function, in young adults, is only slightly altered by hypohydration (28) possibly allowing mental effort and engagement levels to rise during a hypohydrated state. The slight decline in cognitive function manifests through decreased arousal and mood states/feeling states. Additionally, Wittbrodt et al. (38) found increased neural activation in adults when in a hypohydrated state, when performing tasks. These findings justify the increases in mental effort and engagement seen in the hypohydrated states of the participants.

A correlation between the perceptual scores and biometrical analysis can be seen within the present study. When perceived arousal and feeling states decreased with perceived need for fluid consumption increasing, mental effort and engagement scores increased. This creates an inverse relationship between mood state perceptual scores and mental effort and biometrical engagement measurements.

Limitations/Future Research: In the present study, the author is aware that a relatively small sample size likely impacted data analysis in regards to statistical significance.

Increasing sample sizes in the future could reveal greater sensitivity to stimuli in regards to mental effort and engagement due to the close proximity of p-values to the preset alpha. Also, mental effort was unable to be calculated for the live viewing stimulus due to the inability to have the ECHO drink in the iMotions programming.

Future research could possibly include a stimulus demonstrating a live consumption of the beverage used by the participant themselves, as well as, a passive hypohydration trial to account for the impact that exercise may have on mental effort and engagement apart from hypohydration alone. An ad libidium fluid intake trial could also be included to measure if the perceptual need to consume fluids is affecting the engagement and mental effort scores directly.

Mental effort could also be evaluated to find a use within the measurement of fixations over time. With mental effort being defined as the degree of work needed to be done to complete a task, fixations over time needs to be evaluated to quantify that degree of mental effort. The measurement of fixation rates could also be used to predict consumptive behaviors by analyzing the fixation points within separate hydration states. Also, future research could include the measurement of mental effort when given a fixation point to specifically focus on, rather than the fixations seen on fluid consumption. The reduction of fixation rates on fluids through rehydration techniques could indicate the subconscious thoughts of needing to hydrate while in a hypohydrated state rather than fixating on the task at hand, thus taking away focus from the task at hand.

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Table 1. Means and Standard Deviation of physical characteristics and physiological variables.

		Dehydration	
Variable	Baseline	Pre	Post
Age	21.83 ± 1.94		
Height (cm)	180.34 ± 6.82		
Estimated % Body Fat	22 ± 5		
Estimated VO2max (ml/kg/min)	46.67 ± 2.56		
Weight (kg)	72.74 ± 11.46		
Urine Specific Gravity		1.01 ± 0.0094	1.03 ± 0.0046
Urine Color		2.17 ± 0.75	6 ± 0.63
Core Body Temperature (°C)		36.69 ± 0.37	38.16 ± 0.30
% Body Water Loss			2.02 ± 0.09

Demographic data of participants, hydration markers amongst pre and post exercise protocol with core body temperatures.

Table 2. Means and Standard Deviation of perceptual scores.

	Dehydration			
Variable	Pre	Under Trial	Post	P-Value
Feeling Scale	3.83 ± 1.60		2.17 ± 2.23	0.07
Felt Arousal Scale	3.89 ± 1.17		2.5 ± 0.84	0.02*
100 mm VAS	42.67 ± 25.60		90.67 ± 6.59	0.004*
Rate of Perceived Exertion		10.56 ± 2.21		

* indicates significance, p<0.05. *The Feeling Scale (FS) is a likert scale ranked from -5 to +5, the Felt Arousal Scale (FAS) is a likert scale set from 1 to 6, and the 100 mm Visual Analog Scale with anchor points of "I do not want to consume fluids" and "I really want to consume fluids."*

Table 3. Means and Standard Deviation of AOI scores.

	Dehydration			
Varible	Pre	Post	P-Value	R-Value
Video AOI 1	10.15 ± 7.51	19.54 ± 16.75	0.068	0.779
Video AOI2	6.60 ± 6.46	12.18 ± 12.20	0.213	0.595
Video AOI3	6.73 ± 4.58	14.68 ± 10.99	0.349	-0.468
Image 1	9.04 ± 4.89	14.88 ± 14.76	0.002*	0.960
Image 2	9.51 ± 6.90	13.47 ± 9.85	0.346	0.471
Image 3	9.06 ± 4.58	15.31 ± 10.18	0.017*	0.892
Gray 1	5.86 ± 4.18	9.26 ± 6.37	0.398	0.428
Gray 2	9.33 ± 6.19	13.79 ± 12.93	0.273	0.536
Gray 3	12.41 ± 8.85	12.69 ± 11.94	0.049	0.812

** indicates significance, p<0.05. AOI can be defined as the area of interest. Within the AOI the number of fixations over time (seconds) were used to quantify mental effort scores. Within the video commercial three separate activities were preferred with consumption of a carbohydrate-electrolyte sports drinks. These time points of consumption were set as the AOI's.*

Table 4. Means and Standard Deviation of engagement scores.

	Dehydration		
Variable	Pre	Post	P-Value
Video	0 ± 0	22.07 ± 39.48	0.229
Image 1	1.515 ± 3.71	0.78 ± 1.91	0.705
Image 2	0 ± 0	5.33 ± 13.06	0.363
Image 3	0 ± 0	2.17 ± 5.31	0.363
Live View	0 ± 0	13 ± 31.84	0.363

* indicates significance, p<0.05. Engagement scores illustrate facial muscle activation illustrating expressions within the stimulus measured. These scores are set on a scale of 1 to 100.

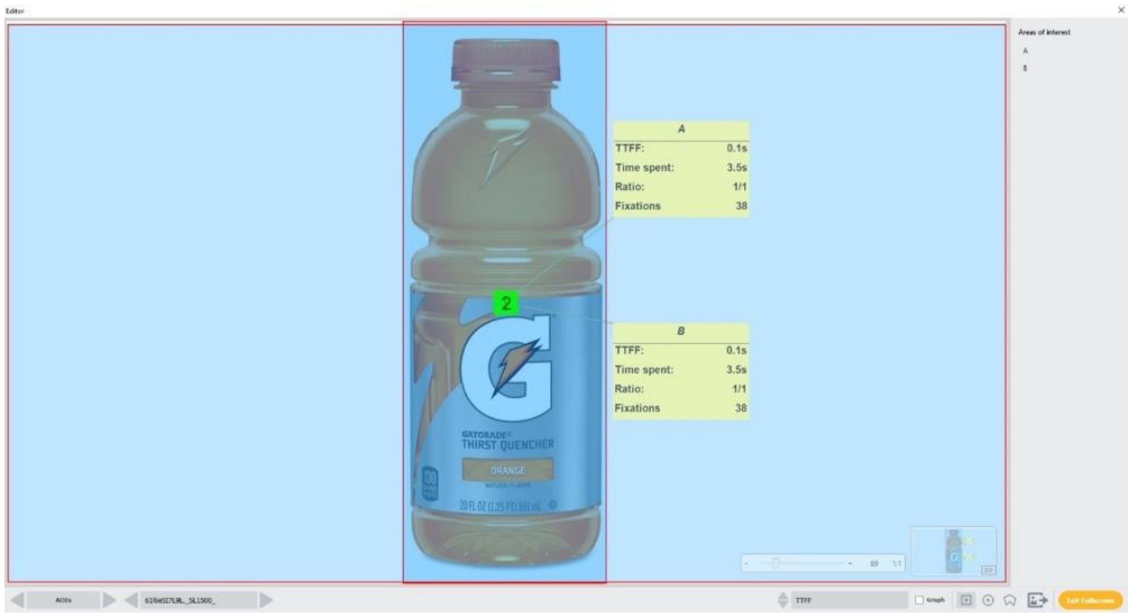


Figure 1. Areas of Interest. AOI A is the bottle. AOI B is the screen.

Figure 2. Heat mapping of image depicting gaze location and intensity prior to exercise trial.

Figure 3. Heat mapping of image depicting gaze location and intensity post exercise trial.

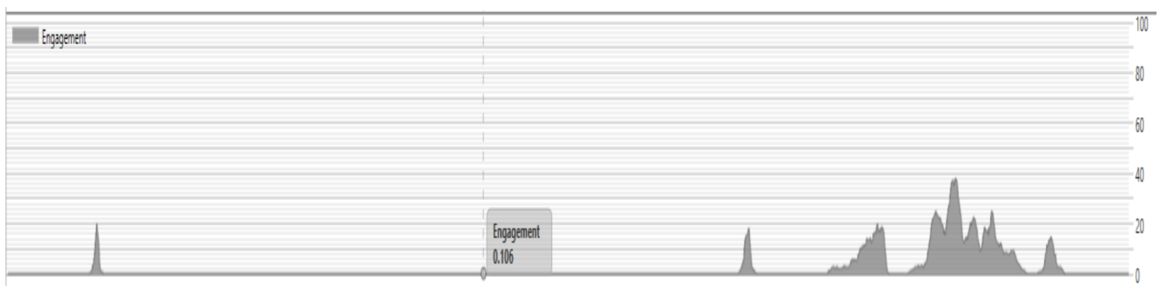


Figure 4. Engagement level reading while viewing stimulus.

Appendix A
AHA/ACSM Health Questionnaire

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire
Assess your health status by marking all *true* statements

History
You have had:
___ a heart attack
___ heart surgery
___ cardiac catheterization
___ coronary angioplasty (PTCA)
___ pacemaker/implantable cardiac
___ defibrillator/rhythm disturbance
___ heart valve disease
___ heart failure
___ heart transplantation
___ congenital heart disease

Symptoms
___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, or blackouts.
___ You take heart medications.

Other Health Issues
___You have diabetes.
___You have asthma or other lung disease.
___ You have burning or cramping sensation in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You are pregnant.

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Cardiovascular risk factors

___ You are a man older than 45 years.

___ You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal.
___ You smoke, or quit smoking within the previous 6 months.
___ Your blood pressure is >140/90 mm Hg.
___ You do not know your blood pressure.
___ You take blood pressure medication.
___ Your blood cholesterol level is > 200 mg/dL.
___ You do not know your cholesterol level.
___ You are > 20 pounds overweight.
___ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive
(i.e., you get <30 minutes of physical activity on at least 3 days per week).

If you marked two or more of the statements in this section you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise program.

___ None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

Appendix B
Feeling Scale

Feeling Scale (FS)
(Hardy & Rejeski, 1989)

While participating in exercise, it is common to experience changes in mood. Some individuals find exercise pleasurable, whereas others find it to be unpleasant. Additionally, feeling may fluctuate across time. That is, one might feel good and bad a number of times during exercise. Scientists have developed this scale to measure such responses.

+5 Very good
+4
+3 Good
+2
+1 Fairly good
0 Neutral
-1 Fairly bad
-2
-3 Bad
-4
-5 Very bad

Appendix C
Felt Arousal Scale

FELT AROUSAL SCALE (FAS)
(Svebak & Murgatroyd, 1985)

Estimate here how aroused you actually feel. Do this by circling the appropriate number. By "arousal" we meant how "worked-up" you feel. You might experience high arousal in one of a variety of ways, for example as excitement or anxiety or anger. Low arousal might also be experienced by you in one of a number of different ways, for example as relaxation or boredom or calmness.

1 LOW AROUSAL

2

3

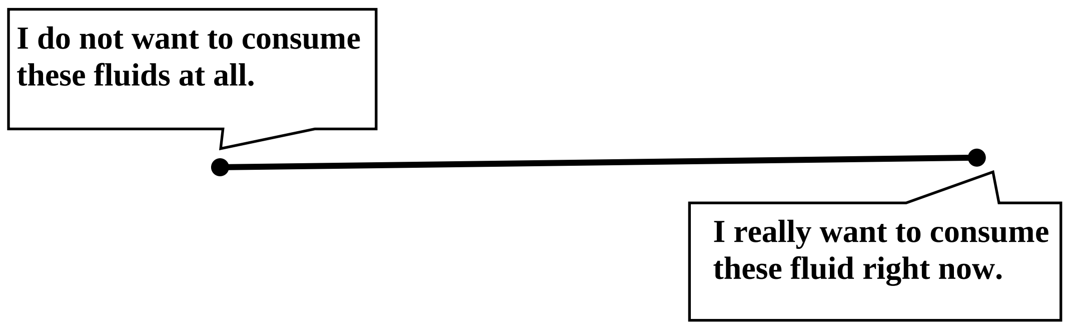
4

5

6 HIGH AROUSAL

Appendix D
100 millimeter Scale

Draw a vertical mark across the horizontal line below to indicate how great your desire to consume these fluids is.



VITA

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