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Auditory Startle Response Predicts Introversion: An Individual Analysis

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We assessed a possible link between the Introversion/Extraversion spectrum and sensori-motor gating and predicted self-reported introverts would have more sensitive sensori-motor gating pathways than extraverts at the individual subject level. 28 subjects self-identified as introverts or extraverts; individuals that self-identified as both introverted and extraverted were classified as "ambiverts". Participants'orbicularis oculus muscles were electromyographically measured while abrupt auditory stimuli ranging from 50 to 100 decibels were played over headphones. As predicted, introverts exhibited greater electromyographical frequencies and magnitudes of response to stimuli at almost all levels of stimulus intensity. These results indicate introverts tend to be more sensitive, on a physiological level, to incoming stimuli compared to extraverts; this finding counters explanations of introversion as a purely social construct. Interestingly, a further and unpredicted pattern of three distinct groups was also observed. These groups are not organized along the lines of introversion/extraversion and may be linked to the concept of neuroticism.

Carl G. Jung (1921) first coined the terms "introversion" and "extraversion" to describe two contrasting attitude types; he considered these attitude types to be distinguishable from one another by the flow of libido, or psychic energy. According to Jung (1921), libido can be directed outwards towards the objective aspect of reality, or inwards towards the subjective aspect of reality. When an individual has an inherent predisposition to place a higher emphasis on the external environment, and thus the objective aspect of reality, the person is said to be extraverted. Likewise, when the individual has an inherent predisposition to place a higher emphasis on the internal environment, and therefore subjective aspects of reality, the person is said to be introverted.

Hans Eysenck's (Matthews & Gilliland, 1997) model of introversion and extraversion was ostensibly quite similar to the Jungian model. However, while Jung's model provided no actual mechanism for an individual's predisposition toward one or the other attitude types beyond the arguably nebulous concept of libido, Eysenck applied modern theories of biology and behaviorism to his understanding of introversion and extraversion. For example, Eysenck (1967) posited introversion and extraversion were tied to cortical arousal. In Eysenck's model, the sensitivity of a particular individual's central nervous system to external stimuli was identified as a strong predictor, if not outright determinate, of introversion or extraversion.

Gray (1970) complimented and expanded on Eysenck's theory of cortical arousal; Gray (1970) proposed an individual's baseline level of cortical arousal, and the ease with which one could be classically conditioned, were the primary factors in determining predisposition toward introversion or extraversion (Matthews & Gilliland, 1997). Compared to extraverts, introverts had a higher base level of cortical arousal, were more sensitive to external stimuli, and were more responsive to punishment cues.

However, Eysenck and Gray's hypotheses differed in the proposed specific mechanism in which cortical arousal arose. Eysenck named two pivotal particular brain systems in his model: the reticulo-cortical circuit, and the reticulo-limbiccircuit (Matthews & Gilliland, 1997).The reticulo-cortical circuit was posited to control the level of arousal generated by external stimuli, and the reticulo-limbic circuit was posited to regulate internal emotional stimuli. In contrast, Gray focused on the septo-hipocampal system which facilitates an individual's interaction and interpretation of the environment by constantly comparing incoming stimuli against abase level of arousal and immediate expectations, then generating pressure toward a response when a discrepancy occurs via the noradrenic bundles of the locus coeruleus (McNaughton & Gray, 2000).

In contrast with both Eysenck's and Gray's neural structural models, which isolate a specific microcircuit within the brain (e.g. the ARAS, or the septo-hippocampal circuit), Sensory Motor Gating (SMG) is influenced by numerous brain structures such as the pre-frontal cortex, basal ganglia, thalamus, hippocampus, and amygdala (Geyer, Krebs-Thomson, Braff, & Swerdlow, 2001;Alsene, Rajbhandari, Ramaker, & Bakshi, 2011). The thalamus serves as a point of convergence for all of the different brain structures that influence SMG (Sherman & Guillery, 2002; Behrendt & Young, 2004; Nichols, 2004). The thalamus is a cluster of nuclei at the top of the brain stem that functions as an information relay center and directs all sensory information to the appropriate section of the neo-cortex for further processing (Sherman & Guillery, 2002). As all sensory information passes through the thalamus, it plays a pivotal role in any neural structure model of personality. The reticular nucleus of the thalamus (RTN) reduces the excitability of the other thalamic nuclei through the neurotransmitter γ-Aminobutyric acid (GABA). The main function of the RTN is to prevent the thalamic nuclei from becoming disinhibited after sending too much information to the neocortex (Behrendt & Young, 2004; Nichols, 2004). Current research points to Thalamic disinhibition as the mechanism behind hallucinations and delusions in sensory-motor flooding disorders like schizophrenia (Behrendt & Young, 2004). Thus, Schizophrenia serves as one salient example of the direct impact thalamic disinhibition can have on behavior. Like Eysenk and Gray, we contend that sensory processing and reaction to stimuli is at the core of the personality constructs of introversion and extraversion. We posit the global brain process of sensory information processing, sensori-motor-gating, is the mechanism that best explains the behavioral differences between introverts and extraverts.

We propose the personality traits of introversion and extraversion reflect the functioning of the SMG system in the individual. Based on Eysenck and Gray's explanations, it follows that the introvert's SMG does not filter out as much information as the extraverted counterpart resulting in hyper-excitability of the neocortex (i.e. cortical arousal).A common, non-invasive method to test SMG is the acoustic startle response. Thus, we posit introverts react to startling acoustic stimuli more than extraverts.

Based on this hypothesis, we designed the following experiment to address three questions. 1) Will self-identified introverts noticeably differ from self-identified extraverts when compared on the basis of the sensory threshold at which they consistently display involuntary physical reflexive responses? 2) Will the magnitude of the responses of self-reported introverts at various stimulus intensities differ from those of self-reported extraverts? 3) Is it possible to identify an individual as an extravert or an introvert based on the individual's involuntary physical reflexive response to sound pulse stimuli? Answering these questions may help elucidate whether or not an objective form of measurement, such as the acoustic startle response, can be used to identify personality characteristics of an individual instead of more subjective means such as self-report surveys.

Methods

Participants

Twenty-eight student participants were recruited for this study (8 males and 20 females), with a mean age of 19.32 years (*SD* = 1.846). The students were awarded class credit for their participation. The sampled participants were racially diverse, with 64% reporting their ethnicity as Caucasian, 7% as Hispanic, 10% as African American, 7% as Asian, and 7% as Native American, with the remaining 5% either reporting themselves as having a mixed heritage, or declining to answer. Of the 28 participants, seven were excluded due to possible confounds induced by self-reported medications (e.g., anti-depressants, stimulants, anti-psychotics) or clinical conditions such as depression or anxiety. The reported procedures were approved by the affiliated Institutional Review Board, approval number: AS1415.

Instruments and Procedures

Participants first responded to a single-item measure of extraversion/introversion in the form of a vignette and a categorical rating scale. The vignette was written as follows:

Introvert: I frequently feel like I am being overwhelmed by my environment. It can be difficult to concentrate on my surroundings because there is just so much going on around me my attention keeps shifting towards every little thing that is going on around me. I generally prefer quieter settings and tend to feel edgy or nervous in environments that have a lot of ambient stimuli. I may even avoid large gatherings of people, not because I am necessarily anti-social but simply because it can be too overwhelming to have that much going on around me at once. When I am in a high energy environment too long I have to have some quality alone time to help recharge my batteries before I can do it again.

Extravert: I very rarely feel overwhelmed by my environment, but I sometimes feel dissatisfied with it. I sometimes find that when I am alone, I become bored and despondent. I prefer to be in the middle of the action, if things get too quiet or still I begin to feel nervous or edgy and feel like I have to go somewhere more lively. I often become easily distracted and find it difficult to focus to if things are too quiet. I prefer to work or study with music or the T.V. playing in the background because I find it easier to concentrate if I have ambient noise in the background. When I feel like my batteries are drained the best way for me to recharge them is to go to a high energy environment. The more going on around me the more I thrive.

Participants were asked to select the description that best characterized their overall personalities and were permitted to select both descriptions, or neither description; thus, we scored a 4-level categorical, nominal response: introvert, extravert, both, or neither. Single-item vignettes have been shown to yield adequate test-retest and predictive validity coefficients when compared to multiple-item measures of the Big Five (see Brown,& Grice, 2011; Grice, Mignogna, & Badzinski, 2011).

Participants also reported medications and medical history and were asked if they had any medical conditions, or if they suspected they had any medical conditions that were undiagnosed. If participants reported taking a medication or drug recently, they were then asked how long they had taken it, and the approximate last time they administered a dose. Participants were also asked about any hearing impairment they had or suspected they had. The hearing ability of the subjects was verified by their ability to hear a 50db stimulus which was the lowest level of stimulus intensity used in this experiment. All participants that reported any medication or drug, medical condition, or hearing impairment were excluded from analysis.

Participants were then tested on the reactivity of their central nervous systems by measuring an acoustic startle response (Blumental et al., 2005). Participants wore headphones through which they were exposed to six sequential audio files. Each audio file contained 3 minutes of silence broken up by eight sound pulses placed randomly throughout the three minute sound file. Each sound pulse was 30 milliseconds in duration. No static, background, or white noise was in the audio files aside from the randomly occurring sound pulses. All audio files were created using Adobe Audition, and each of the audio files was an 8-bit white noise wave form with a sample rate of 4410. A decibel meter was used to calibrate each of the sound files so they would generate a pulse of a specific intensity, each of the six audio files contained a different decibel level ranging from 50dB to 100dB. All of the pulses contained in a singular audio file were of the same intensity(i.e. the first file contained only 50dB sound pulses, the second file only 60dB sound pulses, the third file only 70dB sound pulses, the fourth file only 80dB sound pulses, the fifth file only 90dB sound pulses, and the sixth file only contained 100dB sound pulses). All participants were exposed to the audio files in ascending order, from the lowest stimulus intensity to the highest following a within-subject design. This ascending order of exposure was chosen in order to prevent the participants from becoming desensitized to the lower levels of stimulus intensity due to previous exposure of a higher stimulus intensity.

The electromyographical (EMG) data of the orbicularis oculus muscle of each participant was recorded while the participant listened to the sound files. EMG data were recorded using aBiopac model MP36 apparatus which sampled data at a rate of 500 samples per second. The raw EMG data were filtered through a bandstop filter set at 60hrtz to prevent aliasing from the power outlet. In order to make sure that the recording was accurate, participants were required to swab the area around the eye with isopropyl wipes to remove any makeup, oils, or any other substance that could increase skin resistance. Three general purpose Ag-AgCl electrodes were used for the recording of the orbicularis oculus muscle. Two electrodes were placed under the right eye and the third electrode was placed on the forehead as a ground. Impedance was checked to verify that the resistance between the skin and the electrode was below 10 Kilo ohms. Participants were also asked to blink with the electrodes on before the first sound file was presented in order to insure a clear signal could be recorded.

Data Preparation

Startle responses were analyzed in accordance with the protocol outlined by Blumental et al (2005). The original wave function was duplicated twice in order to preserve the original data. One of the duplicates was passed through an 18-28 hertz bandpass filter in order to help reduce noise and correctly identify hits, or startle responses. In order to be analyzed, the other duplicate wave function was rectified by converting all values to their absolute values. Raw EMG data is converted to absolute values so that the magnitude of response can be compared between individuals. Doing this establishes a true zero (i.e. responses can range from zero to infinity instead of negative infinity to positive infinity). Responses were also manually marked by the researcher to further distinguish between hits and non-hits to reduce the chance of error. A hit was defined as a discernable response to the presentation of a stimulus. An example of a startle response is shown in Figure 1.

Once a response was identified, a smoothing function was used over the range of the response so that data between subjects could be compared (see Figure 2). Each startle response produced three values: amplitude (expressed in microvolts), frequency of response (number of responses per presentations of the stimulus) and muscle tension (the integral of amplitude and duration of response expressed in microvolt x seconds). Each of these variables were averaged within the individual for each decibel intensity. Out of the 28 original subjects, 7 were excluded due to possible confounds induced by medications or medical conditions. Of the 21 remaining subjects, 8 self-identified as introverts, 7 as extraverts and 6 chose both vignettes of introversion and extraversion as descriptive of their personalities. These 6 individuals were referred to as "ambiverts".

Data Analysis

We analyzed the frequencies of responses at each level of stimulus intensity (50lb, 60db…100db) using an ordinal pattern analysis within Observation Oriented Modeling (Grice, 2011; 2014).This method has been used to perform within- and between- subject assessments of a variety of response data at an individual subject level (Craig, Grice, Varnon, Gibson, Sokolowski, & Abramson, 2012; Craig, Varnon, Sokolowski, Wells, &Abramson, 2014; Abramson, Craig, Varnon Wells, 2015) and comparisons between this method and null hypothesis significance testing are assessed and described in Dinges et al. (2013). The ordinal analysis permitted us to focus our analyses on the individuals in our study while avoiding the assumptions required for a parametric analysis such as repeated measures ANOVA (e.g., assumptions of normality, sphericity, continuity). As introversion and extraversion appear in individual subjects rather than in a population parameter that does not exist in reality, assessing aggregate representations would direct our analyses away from our observations, and thus the phenomena under investigation.

The ordinal pattern analysis specifically compares our observations against an *a priori* ordinal prediction. For example, we predicted introverts would have higher response frequencies compared to ambiverts which would have higher response frequencies compared to extraverts (introverts > ambiverts > extraverts). We pooled individual trials of individual subjects into appropriate self-identified groups, and then compared combinations of these individual trials between self-identified groups to determine how well the observed observations fit our ordinal prediction. The number of actual observations that match the ordinal prediction are converted into a percentage and reported as a Percent Correct Classification (PCC) index that ranges from 0% to 100%. Based on our ordinal predictions that support our hypothesis (introverts >ambiverts>extraverts),if every introvert yields higher frequencies than every extravert, then the PCC index will equal 100%. A PCC index of 50% indicates the introverts recorded higher frequencies than the extraverts for half of the person-to-person comparisons, and a PCC index equal to 0% indicates that every extravert recorded frequencies that were equal to or higher than every introvert (the exactly opposite of the ordinal prediction and our hypothesis). A simple, relatively assumption-free binomial probability is also computed for each PCC index under the expectation that the value will equal 50%, indicating no clear difference between the individuals in the two groups being compared.

Results

Response Frequency

Startle responses produced three variables for analysis. The first was frequency of response (F), or the ratio between number of responses (X) over number of stimulus presentations (Y) given in the formula of X/Y = F. The other two variables were measurements of magnitude. The first magnitude variable was amplitude. Amplitude is measured in microvolts and represents the peak of the startle response. The second magnitude variable was muscle tension. Muscle tension is a function of both the amplitude and duration of the response and is expressed in Microvolt·Seconds. Having this raw data allowed us to compare variations of response along self reported personality subtypes. Mean figures were calculated for the average minimal sound level at which introverts and extraverts would present startle response, the frequency of responses among introverts and extraverts along all ranges of noise level, the average muscle tension and magnitude of the physical responses which were displayed by introverts and extroverts, as well as within subjects analyses of all the above.

We assessed if self-reported introverts differed from self-reported extraverts (and ambiverts) with regard to their sensory thresholds when responding to the startling stimuli. We predicted the introverts would show higher frequencies in responding compared to either ambiverts or extraverts, and we predicted the ambiverts to show higher frequencies of responding compared to extraverts. Table 1 reports the PCC indices for all pair-wise comparisons for the introverts, extraverts, and ambiverts (i.e. introverts > ambiverts, ambiverts > extraverts, introverts > extraverts) for each level of stimulus intensity. In addition to performing a series of ordinal prediction analyses, we also plot descriptive median statistics in Figure 3.

Based on Figure 3,the medians suggest the individuals in the three personality groups could not be distinguished from one another for the lower decibel levels of sound, and our ordinal analyses echo this finding; at 50db, the introverts' frequencies were similar to the extraverts' (PCC = 33.93, $p \leq .99$) and ambiverts' (PCC = 29.17, $p > .99$) frequencies. The ambivert individuals were also not distinguishable from the extraverted individuals with regard to their frequencies of responding to the noise at 50db (PCC = 30.95, $p > .99$). However, the introverts can be distinguished from the extraverts (PCCs >66%, $p < .01$) when the stimulus intensity was at 60db, or 80db and higher. Due to two extraverts whose response frequencies increased from 60db to 70db, but then decreased from 70db to 80db, the introverts could not clearly be distinguished from the extraverts at 70db (PCC = 51.79%, $p > .45$). The introverts could also be clearly distinguished from the ambiverts for 90db (PCC = 77.08%, $p < .001$) and 100db (PCC = 66.67%, $p < .01$) stimulus intensity levels. For all levels of stimulus intensity levels, the ambiverts could not be distinguished from the extraverts (all PCCs < 60%, $p > .22$-$.99$). Simply stated, our ordinal analyses revealed introverts had higher response frequencies compared to extraverts and ambivert at stimuli louder than 80db; however we did not observe ambiverts made more responses than extraverts.

Response Amplitude and Muscle Tension

We assessed if the magnitudes of startle responses differed between the three self-reported groups. For both the amplitude and muscle tension measures, we expected the introverts to have larger magnitudes than either the extraverts or ambiverts, and we expected the ambiverts to have larger magnitudes than the extraverts. Figures 3B and 3C show the median amplitude and muscle tension values for the introvert, extravert, and ambivert groups across all six stimulus intensity levels. As can be seen, the medians again suggest the three types of individuals cannot be distinguished for the lowest, 50db level of intensity. Results from the ordinal pattern analyses reported in Table 2 also show that the three types of individuals could not be differentiated based on their amplitude and muscle tension values (PCCs < 50%)at 50db of intensity.

However, for 60db and higher, the introvert participants typically recorded higher amplitudes and muscle tension responses compared to the extraverted participants (PCCs ranging from 66-85.71%, except PCC = 57.14,p>.17 for amplitude at 70db). For 80db, 90db, and 100db, the PCC indices for comparisons between introverts and extraverts were fairly high (ranging from 73.21-83.93%; see Table 2 for p-values). Comparisons between introverts and ambiverts were similarly impressive for muscle tension at 70db and greater, with introverts recording higher values (PCCs ranging from 64-81.25%). The PCC indices for amplitude comparisons between introverts and ambiverts were less impressive, although they indicated the two types of individuals could be distinguished from one another at 90db and 100db (PCCs ranging from 66-68.75%). Lastly, as with the frequency measure, the extraverts and ambiverts could not be clearly differentiated across the intensity levels based on the amplitude or muscle tension values (most PCCs < 50%).

Individual Subject Changes

Considering changes across the six levels of stimulus intensity, we next sought to determine if introverts could be clearly differentiated from the ambiverts or extraverts. We predicted the introvert individuals to have monotonic increases in their frequency, amplitude, and muscle tension measures from 50db to 100db. The medians plotted in Figures 3A, 3B and 3C suggest such monotonic patterns, but Figure 4 shows the individual variability among introverts for the muscle tension measure that is hidden by aggregate plots of medians.

We made a series of ordinal analyses to identify if individuals fit a monotonic pattern (viz., 50db < 60db < 70db < 80db < 90db < 100db) closely for each measure. PCC indices were computed and examined. Five of the eight introverts closely fit the monotonic pattern (PCCs ≥ 73.33%, binomial *p*-values < .06) for all three measures (amplitude, muscle tension, and frequency). The other three introverts did not show monotonic increases on each of the amplitude, muscle tension, and frequency measures. PCC values of at least 73.33% were observed for three of the seven extraverts on each of the amplitude, muscle tension, and frequency measure; this indicates these participants' responses also monotonically increased as stimulus the intensity increased. However, none of the ambiverts showed convincing monotonic increases for all three measures, and two ambiverts failed to show any evidence of startle response across all six decibel levels of intensity for all three measures. The three introverts that could not be distinguished from the extraverts and ambiverts were further examined. Two of these individuals did not reveal a clear monotonic increase in muscle tension as stimulus intensity increased.

Discussion

Based on our ordinal analyses, these introverts had a higher frequency of response to stimuli and greater magnitudes of response both in amplitude and in muscle tension compared to both ambiverts and extraverts. These differences can begin to be seen at stimulus intensities as low as 60db but become much more pronounced at higher levels of stimulus intensities, particularly the 90db and 100db levels.

We asked three questions based on our hypothesis. Based on our findings, self-identified introverts did not noticeably differ from self-identified extraverts when compared on the basis of the sensory threshold at which they consistently displayed involuntary physical reflexive responses. Ambiverts, extraverts, and introverts did not respond at 50dB, and responded similarly at increasingly louder stimuli. However, we did observe response frequency and magnitude differences between introverts and extraverts answering our question as to whether self-identified introverts noticeably differed from self-identified extraverts when compared on the basis of the magnitude of the responses. Finally, our findings indicate higher response frequencies and magnitudes were observed for the majority of introverts compared to extraverts; it maybe possible to identify an individual as an extravert or an introvert based on the individual's involuntary physical reflexive response to sound pulse stimuli. The present findings echo those described in Blumental (2001)which similarly reported introverts to be generally more reactive to startling stimuli than extraverts.

Ambiverts were not clearly discernable from introverts at lower level stimulus intensities, but the difference between ambiverts and introverts is more apparent at the 90db and 100db stimulus intensities. It is interesting to note that ambiverts could not be clearly differentiated from extraverts at any stimulus intensity for any variable that we analyzed. This may be due to the fact that two of the ambiverts had no startle response to any stimulus intensity. Another possibility to this lack of difference pertains to the nature of what an ambivert actually is. Gerogiev (2014) proposed ambiversion as its own unique personality type completely separate from introversion and extraversion.

Based on the present observations, a different model for the concept of ambiversion can be posited. We believe that SMG may be a mechanism behind introversion and extraversion and expect introverts lean towards sensori-motor amplification(e.g. stimuli are not filtered enough, and they tend to produce disproportionate adrenal responses) whereas extraverts are sensori-motor dampeners(e.g. too much stimulus is filtered out, and they do not produce enough of an adrenal response to maintain optimal arousal).It is plausible the SMG occurs on a spectrum with pathological sensori-motor flooding at one end of the spectrum and complete sensori-motor dampening at the other end. According to this model, an ambivert may be someone that switches between the two sides of this spectrum, and thus identifies with both introversion and extraversion; however, at any single point in time, the individual may be functionally either introverted or extraverted.

Personality Discrimination

One of the main goals of this experiment was to see if someone could be identified as an introvert or extravert using a startle response protocol. Our results indicate a biological variance does exist between introverts and extraverts, particularly in the magnitude of response at the higher level stimulus intensities (90db and 100db). At 90db stimulus intensity, introverts had a greater magnitude of response than extraverts over 80% of the time. While 80% is an overwhelming majority, it raises the question of "why didn't introverts respond higher than extraverts 100% of the time"? It is possible that certain individuals misidentified as introverts or extraverts. Our self-report personality qualification process was both novel, and brief. It is also worth noting that our vignettes were not perfectly in line with the wider known social model of introversion/extraversion, a model most pools of undergraduate students, drawn primarily from psychology classes, are already familiar. This may have resulted in individuals choosing the option that they would normally chose for the social model of introversion and extraversion instead of the one we described. Furthermore, it is likely that individuals who are closer to the middle of the sensori-motor gating spectrum, that do not filter out or amplify too much sensory information, could have similar startle response tendencies. It is for these reasons we believe further testing and refinement of the reported protocol are necessary before this measure can be used to definitively categorize personality types.

As for other subjects closer to middle of the sociability spectrum, our results indicate self-identified ambiverts were more similar to extraverts than introverts during the experiment; this would also explain the complete lack of response from two of the ambiverts that were tested. A lack of a startle response may be an example of near total sensori-motor dampening. We observed over 80% of introverts had higher levels of muscle tension, amplitude, and response frequency compared to extraverts and ambiverts at the 90db stimulus intensity level. Continuing to refine the presently reported methods may produce an objective physiological personality assessment in the future. Doing so could benefit personality psychology in two related manners. Most obviously, self-report measures would not necessarily need to be the primary means of collecting personality data. However, a potentially more important contribution of this method would be the utilization of continuous quantitative measurement to identify individuals as introverts or extraverts. Personality psychologists often treat discrete categorical data as if these observations are continuous quantitative measures; this theoretical and methodological divorce could potentially be avoided via a physiological measure of personality. Simply stated, we hope utilizing a physiological measure may help bring personality psychology move from qualitative self-reports to continuous quantitative physiological measurement.

General Discussion

Assessing a physiological measure's relationship with personality characteristics is certainly not a novel aim. Spangler (1997) observed cardiac system activity, cortisol, and immune globulin and personality characteristics were related to ego-resiliency; Cloninger (2002) reports a neuroanatomy of personality; and Turner, Hudson, Butler, and Joyce (2003) describe personality types based on functional brain levels. More relatedly, Corr et al. (1995) observed eyeblink reflexes to pleasant versus unpleasant visual and auditory stimuli. However, Corr et al. (1995) only observed differences in extraversion for response latency, but not for response amplitude or frequency; we observed differences in amplitude and frequency for introverts versus ambiverts or extraverts. However, these physiological personality assessments were not used akin to a personality inventory, and we were able to correctly identify the majority of our individual subjects' self-reported personalities, though refining these methods and increasing sample sizes and the diversity of the sampled population will be important for future assessments.

One of the benefits of our use of Observation Oriented Modeling was our ability to focus our analyses on individual subjects without taking representative aggregates. We contend that personality constructs occur in the individual subject; hence, abstracting to aggregate analyses may not allow researchers to categorize individual subjects as introverts, extraverts, or ambiverts. We were able to trace the majority of our individual subjects through our proposed model; this would not have been possible using traditional null hypothesis significance testing. Observation Oriented Modeling assessments may be especially beneficial for researchers in a subfield interested in assessing individual differences such as personality.

As our proposed model is one of sensori-information processing, we posit personality need not be interpreted from a social paradigm and do not contend an introvert would necessarily be less social than their extraverted counterpart as articulated by Plomin (1976).Instead, our model aligns with that reported in Blumental (2001); an introvert may become overwhelmed by an abundance of sensory information, particularly in a novel setting, but that does not preclude them from enjoying social interaction or necessitate their avoidance of it, especially if they are in a familiar setting.

The personality construct "neuroticism" may be useful in making more accurate predictions in how introverts and extraverts will respond to stimuli; neuroticism could be related to basal levels of norepinephrine in the brain which would affect to what extent one is extraverted or introverted. George et. Al (2013) found rats that had been exposed to prolonged stress had lower levels of basal norepinephrine and an exaggerated response to stimuli. Additionally, Bondi et.al. (2007) observed rats that were given the selective-norepinephrine-reuptake-inhibitor, desipramine, had a robust increase in basal NE levels but decreased response to stressors.

Considering the presently reported model, a neurotic introvert would have a low basal level of norepinephrine and subsequently a higher response to startle stimulus. In contrast, a neurotic extravert would have high basal levels of norepinephrine and a weak startle response to stimuli. Indeed, this interplay between neuroticism and extraversion/introversion may explain the three distinct response patterns the authors found in the amplitude variable (Figure 5). Fourteen out of 21 subjects fell into one of these three patterns, and not one of the patterns was homogenous in terms of the personality constructs introversion, extraversion and ambiversion (Figure 6).If these patterns of responses can be replicated, they may compliment our attempts to identify a comparative startle response threshold to empirically identify personality types using a startle response protocol.

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Appendix

Table 1

Response frequency Percent Correct Classification (PCC) indices for comparing pairs of introvert (I), extravert (E), and ambivert(A) individuals at different levels of stimulus intensity.

Ordinal Prediction	I > E		I > A		A > E	
Stimulus Intensity	PCC	*p*-value	PCC	*p*-value	PCC	*p*-value
50db	33.93	.99	29.17	>.99	30.95	>.99
60db	66.07	.01	54.17	.33	45.24	.78
70db	51.79	.45	37.50	.97	45.24	.78
80db	71.43	<.001	52.08	.44	57.14	.22
90db	80.36	<.001	77.08	<.001	42.86	.86
100db	67.86	.01	66.67	.01	42.86	.86

Table 2

Amplitude and muscle tension percent correct classification (PCC) indices for comparing pairs of introvert (I), extravert (E), and ambivert(A) individuals at different levels of stimulus intensity.

Ordinal Prediction		I > E		I > A		A > E	
	Stimulus Intensity						
Measure		PCC	*p*-value	PCC	*p*-value	PCC	*p*-value
Amplitude							
	50db	32.14	>.99	29.17	>.99	28.57	>.99
	60db	67.86	.01	43.75	.84	47.62	.68
	70db	57.14	.17	50.00	.56	54.76	.32
	80db	78.57	<.001	56.25	.24	61.90	.08
	90db	83.93	<.001	66.67	.01	47.62	.68
	100db	73.21	<.001	68.75	.01	54.76	.32
Muscle Tension							
	50db	28.57	>.99	33.33	.99	28.57	>.99
	60db	66.07	.01	52.08	.44	47.62	.68
	70db	76.79	<.001	70.83	<.001	54.76	.32
	80db	76.79	<.001	64.58	.03	61.90	.08
	90db	85.71	<.001	81.25	<.001	47.62	.68
	100db	75.00	<.001	75.00	<.001	47.62	.68