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Table of Contents

A Little Goes a Long Way: Pressure for College Students to Succeed

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ABSTRACT

When college students begin college they experience pressure from multiple sources. For example, they experience pressure from their parents to succeed, from their professors, and pressure from themselves to do well in classes. This pressure could lead to high anxiety and possibly even poor performance in classes. Prior research that has examined the impact of anxiety on performance includes the Yerkes-Dodson law and the Processing Efficiency Theory. Both argue that anxiety increases the performance to a point, but then performance decreases again with too much pressure. The Processing Efficiency Theory also includes motivation. This motivation increases the drive to succeed and perform at a higher level. In the current study I manipulated the pressure participants felt as they completed a memory test to examine pressure as an influence on memory performance. Furthermore, I also analyzed how trait-anxiety interacts with pressure (as measured by the State Trait Anxiety Inventory). College students ($n = 67$) were separated into either a no pressure condition or a pressure condition and completed a memory test. Results showed a trend for participants with low trait-anxiety to have increased memory performance in the pressure condition. These results follow the Processing Efficiency Theory and the Yerkes-Dodson law. In other words, perhaps participants had better memory in the pressure condition because they were motivated to do well. Future research identifying the optimal amount of pressure for the best performance is suggested.

Keywords: anxiety, pressure, memory, processing-efficiency theory, performance.

INTRODUCTION

College students experience pressure in school every day by their parents, professors and even from themselves to succeed in their classes. That pressure may lead to anxiety. Anxiety is the most common mental illness in the United States, with the onset occurring most often between the ages of 18 and 22 years old (Andrews & Wilding, 2004). Anxiety is especially high amongst college freshman (Vye & Welch, 2007). For college students, pressure from peers to socialize, parents to succeed in school, and an internal drive to succeed, along with being in a new environment, could lead to high anxiety and poor performance in classes (Cassady and Johnson, 2002). Research that has examined the effects of anxiety on performance has used the State Trait Anxiety Inventory (Spielberger, 1983). This standardized assessment splits anxiety into state-anxiety and trait-anxiety. State-anxiety is feelings of nervousness that can be attributed to the present situation. Trait-anxiety is feelings of nervousness that can be attributed to a person's personality characteristics (Spielberger, 1983).

According to Eysenck (2013), performance is based on one's level of state-anxiety. The STAI contains a total of 40 items, 20 items to measure state-anxiety and 20 items to measure trait-anxiety. A typical item to measure state-anxiety is "I feel nervous and restless," and the participant answers on a four-point Likert scale ranging from 1 (almost never) to 4 (almost always). The STAI has a Cronbach alpha coefficient of .90 (Spielberger, 1983). State-anxiety could be brought on by experience of pressure such as the type of pressure college students experience to do well in classes. This type of anxiety could be associated with the autonomic nervous system response to stress, also known as the "fight or flight" response (Viljoen, Claassen & Mare, 2013).

Furthermore, Sarason (1984) states that participants who feel anxiety also experience cognitive interference in the form of preoccupying and concerning ideas, known as "task-irrelevant thoughts." For example, these intrusive thoughts take cognitive resources away from the task and the participant is left with fewer available cognitive resources to complete the task. Conversely, those who report lower anxiety levels have fewer "task-irrelevant thoughts" (Derakshan & Eysenck, 2009). A concept known as stereotype threat could explain why people have these thoughts. Stereotype threat is when someone has a

negative belief about themselves and they are worried that they will confirm this negative stereotype about themselves or their own group (Steele & Aronson, 1995). In other words, if participants begin an experiment thinking that they are going to fail, they are more likely to perform poorly (Chung, B. G., Ehrhart, M. G., Ehrhart, K. H., Hattrup, K. & Solamon, J., 2005). The negative stereotypes that participants have of themselves are the task-irrelevant thoughts.

The Yerkes-Dodson law (1908) has been used to examine the relationship between anxiety and performance. In concordance with the Yerkes-Dodson law, an individual's performance levels will follow a standard bell curve in relation to the amount of pressure applied. Therefore, performance on a difficult task is low with slight amount of pressure, high with an intermediate amount of pressure, and low with a high amount of pressure. The results of Yerkes' and Dodson's experiment showed that there was an optimal amount of pressure that increased performance in rats (Yerkes & Dodson, 1908). The results found by Yerkes and Dodson that lead to the development of the Yerkes-Dodson law have been examined and replicated many times over the past century (Diamond, 2005; Dodson, 1915; Salehi, Cordero & Sandi, 2010). However, the Yerkes-Dodson law does not include a motivational element, where the drive to succeed effects performance level. The processing efficiency theory (PET), which does include a motivational element, could help explain why participants perform better under medium pressure conditions. The processing efficiency theory states that the more pressure a participant experiences, the more effort the participant will exert to perform well up to an optimal amount of pressure (Eysenck and Calvo, 1992).

Since the Yerkes-Dodson law states that performance levels follow a bell curve pattern as the level of stress increases than an excessive amount of stress leads to performance detriments. The idea that performance decreases with pressure has been illustrated and replicated many times. For example, a study by Horikawa and Yagi (2012) identified 59 college soccer players that had high or low anxiety group based on their responses on the STAI. Next, they had them take penalty kicks while their coach pressured them to shoot better or did not give any instruction. The results indicated that both high and low anxiety groups' performance deteriorated under pressure.

In contrast, a study by Walkenhorst and Crowe (2009) showed that a little pressure can actually increase performance. They tested 60 participants that were either high or low anxiety groups based on their STAI responses. They then randomly assigned each participant to a high or low worry group. The high worry condition participants were instructed to sit for fifteen minutes and worry about any topic of their choice and then take a visual patterns test, whereas the low worry group just took the memory test. Results found that low trait-anxiety participants performed best when they were in the high worry condition. This pattern of results is noteworthy because it does not fit with the Yerkes-Dodson law that participants' performance on a task decreases with pressure. Furthermore, participants in the high worry condition would have had task-irrelevant thoughts, which then would have taken away cognitive resources from doing well on the task (Sarason, 1984; Derakshan & Eysenck, 2009). However, the Processing Efficiency Theory could explain this pattern of data because it argues that the participant's motivation to succeed would increase with some pressure resulting in improved performance (Eysenck & Calvo, 1992).

The purpose of this study is to examine whether manipulated pressure on college students will affect their memory performance on a cued-recall test. I hypothesized that overall, participants with high trait-anxiety will have worse memory performance compared to participants with low trait-anxiety. Furthermore, I hypothesized that pressure will negatively affect all participant memory performance, with pressure having the most deleterious effects for participants with high trait-anxiety.

METHOD

There was 67 participants selected from the South Dakota State University Psychology Department research participation pool (50 female, M age = 18.76). This experiment used a 2 Condition (no pressure and pressure) x 2 Anxiety (high trait-anxiety and low trait-anxiety) between subjects analysis of variance (ANOVA) design. Participants were randomly assigned to Condition and completed the trait portion of the State Trait Anxiety Inventory (Spielberger, 1983). Based on participants' responses, I created a low trait-anxiety group and a high trait-anxiety group using a median split. I selected the memory

test items from a norming study completed by Grimaldi, Pyc and Rawson (2010) based on the probability they were recalled during Trial 1 of the norming study. The average probability of recall on trial one was .23, but items from the entire range were selected (.04-.49 probability of recall).
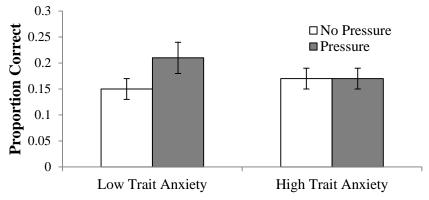
PROCEDURE

Participants were first given an information sheet about the study and agreed to participate. Immediately after agreeing to participate, all participants completed the trait portion of the State Trait Anxiety (STAI). After completing the trait-anxiety portion of the STAI, participants in the no pressure condition heard, "You are about to study some easy word pairs, try to the best of your abilities." Participants in the pressure condition heard, "You are about to study some very difficult word pairs and your performance on the memory test will be indicative of your other abilities such as performance in classes, overall GPA, and expected earnings in the workplace." The participants were then shown 40 Lithuanian-English word pairs each for 10 seconds (e.g., durys-door) using Superlab (Cedrus, 2013). After participants viewed all 40 word pairs they began the memory test in which they were given a sheet of paper with all 40 Lithuanian words and were asked to provide the English equivalent (e.g., durys -   ). Participants attempted to recall the word pairs for 6 minutes. Finally participants were asked to complete a series of demographic questions. In the debriefing, participants were informed that the purpose of the study was to find out whether manipulated pressure on college students affected their memory performance.

RESULTS

I conducted a 2-way analysis of variance (ANOVA) with Condition (no pressure and pressure) and Anxiety (high trait-anxiety or low trait-anxiety) as the between subjects independent variables and memory performance as the dependent variable. The results revealed that there was no main effect of the Condition, $F(1,63) = 1.82$, $MSE = 0.01$, $p = 0.18$, $\eta^2_p = 0.03$. In other words, participant memory performance in the no pressure condition ($M = 0.16$, $SE = 0.02$) was no different than participant memory performance in the pressure condition ($M = 0.19$, $SE = 0.02$). Similarly, participant memory performance in

the low trait-anxiety group ($M = 0.18$, $SE = 0.02$) was no different than participant memory performance in the high trait-anxiety group ($M = 0.17$, $SE = 0.01$; $F(1,63) = 0.31$, $MSE = 0.01$, $p = 0.58$, $\eta^2_p = 0.01$. Finally, there was no interaction between the pressure condition and trait-anxiety, $F(1, 63) = 1.44$, $MSE = 0.01$, $p = 0.23$, $\eta^2_p = 0.02$. Students who have high trait-anxiety were no more likely to perform well on a memory test than students with low trait-anxiety, regardless of condition (see Figure 1).

Figure 1. The percent correct on the memory test, comparing trait-anxiety and pressure condition. The error bars depict standard error

DISCUSSION

The goal of this research was to determine whether manipulating pressure on participants would affect their performance on a memory test. The high trait-anxiety participants had similar memory performance regardless of the pressure condition. The expectation was that the memory performance would be higher in the low pressure group; however there was a slight indication that pressure improved memory performance for people with low trait-anxiety. As such, it is possible that those with low trait-anxiety needed some pressure to be motivated to perform at a higher level, which follows the Processing Efficiency Theory and Yerkes-Dodson law in that the optimal amount of pressure results in increased performance. If this law was valid for pressure on students in college in real classroom settings, then one could infer that some pressure would be better than no pressure.

Some potential limitations of this experiment include external validity and the anxiety measurement. Putting pressure on an individual in a controlled environment is much

different than applying real life pressure, such as a parent or a professor in a natural situation, thus reducing external validity. Additionally, the state portion of the State Trait Anxiety Inventory was not used in this experiment. Future research in this area should use the state portion of the assessment to check if the pressure manipulations are effective at increasing state anxiety. It is possible that participants in the current experiment were not anxious for various reasons including that they were not listening to the instructions that were intended to cause the anxiety or that participants were not affected by the low severity of the pressure. Another check of state-anxiety could have been participant's subjective reports, but no reports were collected. For example, I could have asked participants how they perceived the pressure put on them.

Participant's trait-anxiety level in the current sample was low, which may have skewed the results. The State Trait Anxiety Inventory (Spielberger, 1983) ranges in scores from 20 to 80, so the mean should be 50, but in this sample both the mean and median were 37, which is much lower than the ideal mean. Increasing sample size to have a more representative sample would allow one to make better conclusions about how pressure and anxiety interact to influence memory performance.

Although some studies concerning anxiety focus on physiological responses to stress or pressure, this study focused on the cognitive effects of anxiety. Cognitive effects of anxiety, including task-irrelevant thoughts, affect college students and have deleterious effects on memory performance and performance on other tasks (Derakshan & Eysenck, 2009). In this study the task-irrelevant thoughts could have been focused on the fact that results of the memory test were "indicative of performance in classes, overall GPA, and expected earnings in the workplace." Although the results were not statistically significant there was a trend that high pressure led to increased performance on the memory test. This could be explained by the Processing Efficiency Theory (PET), stating that the more pressure a participant experiences, the more effort the participant has to exert to perform well.

Although people may be tempted to decrease anxiety, my results and results from previous research (Yerkes & Dodson, 1908; Eysenck and Calvo, 1992) suggest that there is an

optimal amount of anxiety, stress or pressure for performance on a given task, including

memory. Future research should identify optimal amount of pressure to increase

performance on a variety of tasks in more naturalist settings such as the college classroom.

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Identifying Promising New *Falcata* Alfalfa Populations for Use in Semiarid Rangelands

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ABSTRACT

Alfalfa (*Medicago sativa* L.) is a valuable crop worldwide. In addition to its use as forage, the nitrogen fixation capabilities of root nodules make it a valuable component for improving soil health. Unfortunately, the semi-arid region of the Northern Great Plains introduces a number of environmental stresses that are detrimental to stand establishment and persistence. The ability to produce adventitious shoots from roots is generally considered a favorable trait for increasing stress resistance. This study aimed to identify alfalfa populations possessing the ability to produce adventitious shoot from root segments. Seven Plant Introductions (PIs), selected from the National Plant Germplasm System, and one commercial cultivar (Persist II) were evaluated. Two 6cm root segments originated at 1cm and 7cm below the cotyledonary node from 1-year-old plants. Root segments were planted in Miracle-Gro® potting soil for 16 weeks. Adventitious shoot emergence was recorded throughout the experimental period. At the end of the experimental period, a number of root segments that produced adventitious shoots, shoot survival, status of flowering and non-shoot-bearing root segment decay were determined. Six of the seven PIs produced adventitious shoots. No shoots produced on Persist II and PI 494662 roots. Among the six populations, frequency of generating adventitious shoots from roots ranged from 3.8% to 57% and frequency of shoot survival varied from 33% to 100%. Speed of regeneration from roots and viability of root segments in soil varied among populations. PI 631678 had the greatest frequency and speed of regeneration from roots, high survival and flowering frequencies. Little difference in adventitious shoot regeneration and survival related to distance below the cotyledonary node within the same populations.
Keywords: alfalfa, adventitious shoot, emergence, root

INTRODUCTION

Alfalfa is a valuable forage crop in North America. High protein content makes it an excellent complement to corn silage, lessening and sometimes eliminating the need for protein supplements. Also possessing relatively high concentrations of calcium and mineral, alfalfa is particularly valuable for dairy cattle (Jennings, 2014). In addition to the nutritive value alfalfa possesses as a forage crop, the nitrogen fixation properties of alfalfa roots make it a valuable component in soil fertility management. In the semi-arid regions of the Northern Great Plains, yellow-flowered alfalfa (YFA) (*Medicago sativa* subsp. *falcata*) holds a particular interest.

YFA has become naturalized to semi-arid climate conditions in the Grand River National Grassland of South Dakota (Xu et al, 2005). Alfalfa has traditionally been plagued by difficulties in seed germination and stand establishment in this region. These difficulties stem from extreme climate variations: drought, extreme cold, and grazing pressures from cattle. Overcoming these difficulties would be beneficial for this valuable forage crop.

Adventitious growth is vegetative reproduction that occurs from a living portion of a parent plant, instead of from a seed. This ability is generally considered favorable for increasing stress resistance in plant populations, particular in environments when seed production is unreliable under grazing, stand establishment from seedlings, and persistence is poor. Adventitious shoots developed on the roots of alfalfa is an uncommon phenomenon. First observation, reported in the literature, was made in South Dakota by Oakley and Garver (1913) on a strain of YFA, originating from Orenburg, Russia and later strains from Semipalatinsk, Siberia (Oakley & Garver, 1917). Inspired by previous observations, Smith (1950) further studied the capability of YFA to produce adventitious shoot growth from root segments. Heinrichs (1954) suggested the adventitious shoot production on the alfalfa is genetically conditioned. If this trait could be cultivated in commercial YFA populations, the stress resistance of this valuable crop could be increased. Alfalfa has been shown to respond to intersubspecific hybridization (Riday & Brummer, 2006), and it is hoped that these difficulties may be overcome by introducing stress resistant traits such as adventitious growth potential.

The objective of this study was to identify Plant Introduction populations of YFA possessing the ability to produce adventitious shoot growth from root segments and to evaluate effects of root segments cut below the cotyledonary node on adventitious shoot regeneration and survival.

MATERIALS & METHODS

Seed Source

The seeds of the eight population entries used in this study were obtained from a commercial Millborn Seeds company (Persist II) as control and seven PIs from National Plant Germplasm System (PI491407, PI494660, PI494661, PI494662, PI631677, PI631678, and PI631682). PIs were selected based upon the origin latitudes and climates similar to South Dakota (Table 1).

For each entry, 100 uniform seeds were selected, scarified, and inoculated with *Rhizobium* before planting in individual 164ml plastic cell containers (Ray Leach "Cone-containers"; Stuewe and Sons, Inc., Tangent, OR) filled with Mircle-Gro® potting soil. Seedlings completed first year dormancy under ambient day and night photoperiod cycle in a greenhouse located in Brookings, S.D.

Experimental Procedure

From each entry, there were 25 to 50 healthy 1-year-old plants randomly selected and excavated for assessment of the ability of root segments to produce adventitious shoots. After removal of soil and lateral roots, each taproot was cut into two 6cm segments originating at 1cm and 7cm below the cotyledonary node. Three root segments of each entry were planted upright in an 11.5cm dia. X 9.5 depth plastic pot filled with Miracle-Gro® potting soil. Pots were maintained in a greenhouse with 16h light/8h dark photoperiod, 24±3°C temperature, and watered daily by misting.
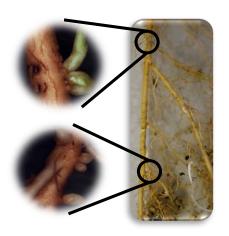
Table 1: Eight alfalfa populations were evaluated for the ability to produce adventitious shoots from root segments.

Entry	Description	Marketer/Origin
PI491407	*M. sativa* subsp. *falcata, NPGS*	China, Nei Monggol (Inner Mongolia)
PI494660	*M. sativa* subsp. *falcata, NPGS*	Romania, Lat. 46° 46'0" N, Long. 23° 36'0"E
PI494661	*M. sativa* subsp. *falcata, NPGS*	Romania, Lat. 46° 46'0" N, Long. 23° 36'0"E
PI494662	*M. sativa* subsp. *falcata, NPGS*	Romania, Lat. 44° 19'0" N, Long. 23° 48'0"E
PI631677	*M. sativa* subsp. *falcata, NPGS*	Mongolia, Lat. 49° 49'32" N, Long. 92° 03'48"E
PI631678	*M. sativa* subsp. *falcata, NPGS*	Mongolia, Lat. 49° 46'40" N, Long. 91° 53'52"E
PI631682	*M. sativa* subsp. *falcata, NPGS*	Mongolia, Lat. 48° 10'33" N, Long. 91° 45'29"E
Persist II	*M. sativa,* Cultivar, Conventional Hay-Type	Millborn Seeds Inc.

Data Collection

Shoot emergence was recorded daily and tallied weekly. Shoot-bearing root segments were moved to individual pots after one to two weeks of emergence to ascertain the exact root segment had produced the shoot (Fig. 1). Flowering plants were hand-pollinated to evaluate the capability of sexual reproduction. At the end of 16-week period following planting, a number of root segments that produced shoots, shoot survival, and status of flowering on survived shoots were determined. The non-productive samples were excavated to detect whether root segments had decayed over the course of the project or were unproductive.

Data Analysis
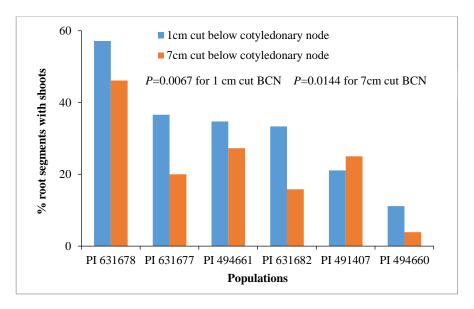
Figure 1: Adventitious buds on the roots of PI 63168 (left) and adventitious shoot-bearing root segments are displayed (right).

Frequency of shoot regenerated from root segments was calculated by using the number of root segments producing adventitious shoots that appeared above the soil surface divided by the total root segments planted for each distance below the cotyledonary node, respectively. Percentage of shoot survival was calculated based on the number of shoot-bearing root segments whose shoots survived by the end of the 16-week period. The percentage of surviving shoots that produced flowers was also calculated by the end 16-week study period. Entries of Persist II and PI 494662 were excluded from data analysis because no shoots generated from the root segments. Frequency of generating shoots from root segments was analyzed using PROC FREQ (SAS, 1990). A Chi-square (χ^2) analysis was used to detect the differences (*P<0.05*) among the six populations and among distance below the cotyledonary node.

RESULTS

Of the eight populations of alfalfa used in this study, no shoots generated on PI 494662 and Persist II root segments. Frequency of generating shoots from root segments varied significantly from 11.11% to 57.15% among six PIs for 1cm cut below the cotyledonary
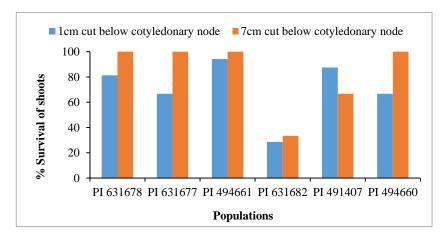
node (P=0.0067) and 3.85% to 46.15% for 7cm cut below the cotyledonary node (P=0.0144) (Fig. 2). It was the most frequently occurred in PI 631678 (57.15% and 46.15%) for 1cm and 7cm cutting distances below the cotyledonary node, respectively, and least frequently in PI 494660 (11.11% and 3.85%) (Fig. 2).
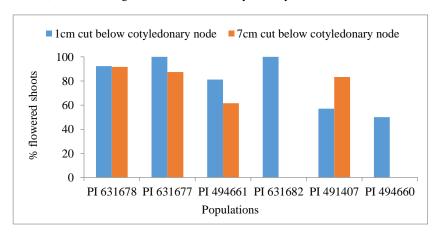
Figure 2: Among the six PIs, the frequency of generating shoots from roots ranged from 11.11% to 57.15% for 1cm cut below the cotyledonary node (P=0.0067) and 3.85% to 46.15% for 7cm cut below the cotyledonary node (P=0.0144).
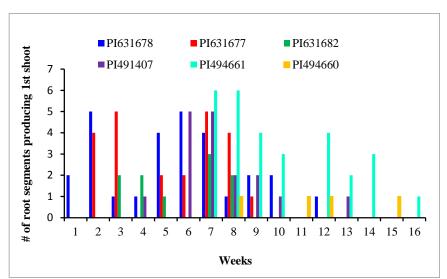
Once adventitious shoots had appeared above the soil surface, survival rate were similar among the productive populations except for PI 631682 (Fig. 3). Furthermore, most surviving plants produced flowers (Fig. 4). If the flowers were hand-pollinated they formed pods and produced seeds (data not shown in the paper). The speed of emergence of shoots had a great variation among the six populations. PIs from Mongolia (PI 631678, PI 631677 and PI 631682) had faster emergence, as early as the first week following planting. Of the root segments with shoots, 80% to 100% appeared by the eighth week. While PIs from Romanian (PI 494661 and PI 494660) shoots emerged much slower and first emergence appeared at the seventh week and 75% to 96% shoot-bearing roots occurred between the seventh and fourteenth week. PIs from Inner Mongolia of China (PI 491407),

displayed 76% shoot production generated during between the fourth and eighth week. The highest occurrence of regeneration occurred across the six PIs during the seventh week. PI 631678 had the greatest speed of adventitious shoot production. In addition, it produced adventitious growth longer than any other populations (Fig. 5). Viability of root segments in soils varied among the populations (Fig. 5). Viability of PI 494661 root segments lasted for 16 weeks (Fig. 5) and displayed a low percentage of non-shoot bearing root segment decay (37%) compared to other populations (52% to 87%) except for PI 494662.

Figure 3. Six PIs showed similar survival rate of emerged shoots, with the exception of PI 631682, for both cutting distances below the cotyledonary node.

Figure 4: Most surviving plants produced flowers across all six PIs, with the exception of PI 631682 and PI 494660 on the 7cm cutting distance.

Figure 5: Speed of adventitious shoot development varied among the populations. PI 631678 produced shoots during the first week after planting and lasted for 13 weeks. While PI 494661 shoot production was delayed until the seventh week. The highest occurrence of regeneration across the six populations was the seventh week. Viability of root segments in soil varied among the populations.

DISCUSSION

Improving yellow-flowered alfalfa's persistence in South Dakota's climate will result in significant economic benefits for livestock producers. Today, this valuable species is limited by poor stress resistance and stand persistence. The first step in increasing stress resistance of the commercial strains is by identifying populations that exhibit the desired traits. This study was the first step in that process.

In order to determine populations that would excel under South Dakota weather, it is important to start looking in areas with a similar environment. Seven populations with latitudes and climates similar to South Dakota were selected. The results of this study suggested that shoot emergence is the most limiting factor for this stress-resistant trait.

Once adventitious growth begins, survival and flowering rates appear to be consistent across the populations (Fig. 3, Fig. 4).

Of these populations, the Mongolian strains seemed to possess higher potential for adventitious reproduction (Fig. 2). Among the examined populations, PI 631678 exhibited the highest frequent production of adventitious shoot, followed by PI 631677 and PI 494661. Both PI 631677 and PI 494661 had similar but less frequent generating shoots from roots segments compared to PI 631678.

In addition to the ability to produce adventitious shoots, one should also consider when this growth begins and how long it lasts (Fig. 5). PI 631678 was the most productive PI in this study, and also exhibited the fastest production (began during the first week) and longest production period of the study (about 12 weeks). Meanwhile, PI 494661 root segments demonstrated the longest viability in soil compared to other populations. From a management standpoint, these traits could have profound implications. In South Dakota, weather is seasonally unpredictable, experiencing late frosts, early thaws, and a wide variability of seasonal temperature and rainfall (Spuhler, 1971). A strong and long production period in addition to long viability in soil could increase the ability of the cultivar to resist the seasonal stresses that South Dakota is capable of producing.

The presented preliminary results suggest that Mongolian strains like PI 631678 and Romania strains like PI 494661 may have a higher potential for adventitious reproduction than PIs examined in the study (Table 1). The results support the value of testing to identify additional populations in the USDA Plant Introduction Collection which express these traits. Future projects may use the information from this study as a starting point for parental material selection. This study is currently being repeated to determine the true vegetative reproductive capability and consistency of these populations.

Once populations have been successfully identified as possessing the ability to produce adventitious shoots on roots, plant breeding programs can begin to integrate the desired traits into commercially available cultivars. By reducing the need for new seed purchase

every year, the value of the alfalfa forage only increases. This translates into increased value for farmers, ranchers, and anyone who has decided to use alfalfa as a forage crop.

LIMITATIONS

This work was conducted under greenhouse conditions. Greenhouse provides a better controlled environmental condition to evaluate the possibility of these phenotypic traits. This study was also done with a relatively small sample size for populations. Future work will entail a larger sample size for each population and a more elaborate experimental design will be employed. Although the results support the value of testing to identify additional populations in the USDA Plant Introduction Collection which express these traits, evaluation under field conditions should precede any selection effort.

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Integration of a Pulsating Heat Pipe in a Flat Plate Heat Sink

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ABSTRACT

The ongoing development of faster and smaller electronic components has led to a need for new technologies to effectively dissipate waste thermal energy. The pulsating heat pipe (PHP) shows potential to meet this need, due to its high heat flux capacity, simplicity, and low cost. A flat plate PHP was integrated into an aluminum flat plate heat sink with a simulated electronic load. The PHP heat sink used water as the working fluid and had 20 parallel channels with dimensions 2 mm × 2 mm × 119 mm. Experiments were run under various operating conditions, and the thermal resistance of the PHP was calculated. The performance enhancement provided by the PHP was assessed by comparing the thermal resistance of the heat sink with no working fluid to that of it charged with water.

Uncharged, the PHP was found to have a resistance of 1.97 K/W. Charged to a fill ratio of approximately 75% and oriented vertically, the PHP achieved a resistance of 0.49 K/W and 0.53 K/W when the condenser temperature was set to 20°C and 30°C, respectively. When the PHP was tilted to 45° above horizontal, the PHP had a resistance of 0.76 K/W and .59 K/W when the condenser was set 20°C and 30°C, respectively. The PHP greatly improves the heat transfer properties of the heat sink compared to the aluminum plate alone. Additional considerations regarding flat plate PHP design are also presented.
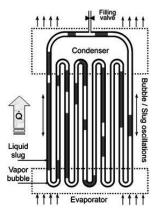
INTRODUCTION

The miniaturization and improvement of performance of electronics has led to thermal management becoming a limiting factor in their development. This has created a need for

devices that can effectively dissipate very high heat fluxes and maintain acceptable electronic temperatures [1]. For many microprocessors, the hottest allowable operating temperature is approximately 90°C. If this temperature is exceeded, the microprocessor's performance and lifetime are negatively impacted. One device with the potential to meet this growing thermal management need is the pulsating heat pipe (PHP), also known as the oscillating heat pipe.

First proposed by Akachi et al. [2, 3], PHPs are simple, two-phase heat transfer devices. Unlike traditional heat pipes, PHPs do not require a wicking system, have a wider range of form factors, are easier to manufacturer, and have fewer operating limits such as temperature range and heat transfer rate. Due to the simplicity of PHPs, they also offer a significant weight reduction, making them ideal for aerospace applications [4].

A PHP can be divided into three main regions: the evaporator, condenser, and adiabatic sections, which are connected by meandering mini-channels (Fig. 1). A two-phase working fluid acts as the heat transfer medium. When the PHP is operating, the working fluid is in a two-phase state consisting of liquid slugs and vapor bubbles. Unstable pressure differentials between the evaporator and condenser sections generate the pulsating motion. The pressure differentials are due to temperature differences between the evaporator and condenser sections. Unlike thermosyphons, PHPs are not highly dependent on gravity [5]. This indicates that PHPs will function in multiple orientations and in micro-gravity environments [6, 7].

Figure 2: Pulsating heat pipe primary components [5], consisting of an evaporator, condenser, and adiabatic section.

Fluid fill ratio, orientation, geometric parameters, and heat input affect the performance of a PHP. A PHP has an optimum fill ratio, the volume of liquid in the PHP compared to the total volume of the channels, generally between 25%-75% [8-10]. Fill ratios outside of this range tend to limit oscillation, reducing heat transfer.

When water is used as the working fluid, the acceptable channel dimensions are limited to the mini channel scale for proper operation, other fluids, such as, refrigerants may operate in the micro channel scale. The channels must be sized appropriately, so the working fluid can create vapor bubbles due to surface tension. Since fluid surface tension is the main driver of channel size, the Bond number (Eq. 1) is often used to give the range of possible channel diameters for PHP operation.

$$Bo = \frac{D^2 g(\rho_l - \rho_v)}{\sigma} \tag{1}$$

It has been shown that there exists an upper Bond number limit for operation, between 3.39 and 4. Similarly, a lower limit exists between 0.36 and 0.49 [6]. If the hydraulic diameter is sized outside this range, the working fluid will be unable to form vapor bubbles and pulsate.

Studies by Yang et al. [11] and Khandekar et al. [12] indicate that thermal resistance can be reduced when square channels have low fill rates and are vertically heated. This is due to the sharp edges of the channels acting as a capillary structure, effectively creating a gravity-assisted thermosyphon. PHPs with high fill ratios and/or circular channels will not see this effect.

Heat input also affects performance. Various analyses of PHP performance indicate that as heat input is increased, the thermal resistance decreases [9, 13, 14]. It has been shown the heat removal rate of the cooling mechanism, i.e. cooling bath or air stream, limits the minimum thermal resistance that can be achieved by the PHP [15].

Flat plate PHPs have been investigated by Khandekar et al. [5]. Transverse heating can be a significant factor in PHP operation. In their study, a flat plate PHP was constructed. It had 2.2 mm x 2.0 mm channels that contained 0.5 mm of aluminum separating each channel. As a result, two adjacent channels with temperature gradients would quickly equalize. This also causes pressure gradients to equalize, mitigating pulsation and heat transfer. It was recommended that heat transfer between channels be reduced to improve performance.

To help improve current PHP performance, innovative design features have been implemented; one example is from Thompson et al. [4]. Such design features utilize a Tesla type check valve to regulate the direction of the fluid flow of the PHP. By promoting fluid flow in one direction, pulsations would be less chaotic. As a result, performance was improved when compared to a PHP without the check valve.

Another design innovation by Thompson et al. [16] was to produce a 3-D PHP. The channel density was much higher than that on typical flat plate PHPs. As a result of the high channel density, the PHP was capable of transferring heat fluxes up to 300 W/cm^2. Design innovations such as these should help to improve PHP performance to make it viable option for thermal management needs.

In this study, a flat plate PHP was developed to meet the cooling needs of small, high heat flux electronics devices and to investigate the operational characteristics of PHPs.

Performance of the PHP will be compared to similar PHPs studied to identify possible improvements for future iterations. This will be done to develop innovative design solutions that may be implemented to enhance the heat transfer capacity of the PHP.

APPARATUS AND METHODS

Apparatus

The PHP apparatus used in this investigation (Fig. 2) consisted of a milled aluminum plate, clear polycarbonate cover, rubber o-ring, and structure for varying the inclination angle. The milled aluminum block (177 mm x 127 mm x 3.75 mm) has channels that are 2 mm x 2 mm x 119 mm with 2 mm of material between each channel. There were 20 channels and 10 turns each in the evaporator and condenser sections, which created a closed-loop PHP. A charging port was machined into one side of the aluminum block. A 6.35-mm transparent polycarbonate plate covered the channels to allow for visualization of the fluid flow. An EPDM o-ring and fasteners created a seal between the aluminum block and polycarbonate cover. The PHP was charged with water that resulted in a Bond number of 0.528, within the operational range determined by previous work.
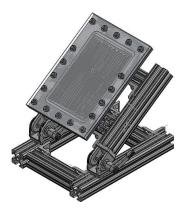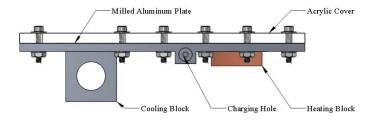

Figure 3: 3-D model of the pulsating heat pipe apparatus.

A heating block was constructed and placed in contact with the backside of the evaporator section of the PHP heat sink (Fig. 3). The heating block consisted of a copper block (83
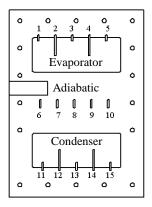
mm x 32 mm x 9.5 mm) with four embedded 100 W cartridge heaters. A 120 VAC variable output transformer was used to control the power supplied to the cartridge heaters. A cooling block was constructed and clamped to the backside of the condenser section of the PHP heat sink. The cooling block consisted of an aluminum block (82.5 mm x 31.75 mm x 31.75 mm). A 50/50 volume percent water/antifreeze solution flowed through the cooling block, removing heat from the PHP. A thermostatic chiller circulated and regulated the temperature of the solution. High-density fiberglass insulation, 2.54 cm thick, surrounded the heating and cooling blocks, as well as the front and back of the PHP heat sink.

Figure 4: Side view of the apparatus displaying major components.

The frame provided a clamping force to ensure good thermal contact between the heating and cooling blocks and the PHP heat sink. Thermal grease was used at the interfaces to minimize contact resistances. The frame was designed to allow easy and accurate adjustment of the inclination angle.

Fifteen 30-gage T-type thermocouples measured the temperatures at five locations in each of the three sections (evaporator, condenser, and adiabatic) of the PHP. The thermocouples were calibrated using a reference thermometer to achieve an uncertainty of ±0.2°C. Channels 0.5 mm deep were milled into the back of the plate so that the thermocouples would read, with greater accuracy, the temperature of the aluminum plate near the working fluid channels. The thermocouples were offset in the direction of heat transfer in the condenser and evaporator sections to obtain better average condenser and evaporator temperatures (Fig. 4).

Figure 5: Thermocouple locations on the backside of the PHP.

Voltage and current transducers were used to measure the power supplied to the heaters. The transducers had uncertainties of 1% and 0.5% for current and voltage, respectively. A data acquisition system was used to record the data from the thermocouples and transducers at a rate of 1000 Hz. Once steady state had been reached, average values were determined over a five-minute period. Steady state was determined to be reached if the standard deviation of the evaporator temperature was less than 0.5°C over a five-minute period.

Procedure

The PHP was evacuated prior to testing using a vacuum pump capable of achieving pressures of 2 Pa absolute. Then degassed, deionized water was added to the PHP until the desired fill ratio was obtained. The inclination angle was next set to the appropriate angle for the test. Depending on the condenser condition desired, a cooling bath was used to maintain the condenser temperature at 20°C or 30°C. A heat input between 10W and 110W was supplied by the heater block. At each power input, the system was allowed to reach steady state. This process was then repeated at a tilt angle of 45° above horizontal. The fill ratio for all experiments was 75% ± 5%.

Heat Loss Estimation

In order to account for heat losses to the ambient, a heat loss experiment was conducted. This was accomplished by testing an uncharged (dry) PHP. As the power input was varied, the evaporator, condenser, and ambient temperature were measured. Using the evaporator and condenser temperatures and the published values for conductivity of aluminum 6061-T651, the heat transfer due to conduction through the PHP was found (Eq. 2). The conduction heat transfer was subtracted from the total heat input to find the heat loss (Eq. 3). Next, a relationship between heat loss and the difference between evaporator and ambient temperature was developed (Eq. 4). This relationship was used to account for heat loss in the experiments.

$$Q_{cond} = \frac{(T_E - T_C)(A_{xs})(k)}{x} \tag{2}$$

$$Q_{loss} = Q_{in} - Q_{cond} \tag{3}$$

$$Q_{loss} = .2707(T_E - T_A) - .3565 \tag{4}$$

Data Reduction

To determine the temperatures of the evaporator and condenser sections, an average of the five thermocouples in each section is determined (Eq. 5 and Eq. 6).

$$T_E = \frac{1}{5} \sum_{i=1,2,3,4,5} T_{max,i} \tag{5}$$

$$T_C = \frac{1}{5} \sum_{i=11,12,13,14,15} T_{min,i} \tag{6}$$

The power input to the system was found from the product of the voltage and current transducers (Eq. 7).

$$P = VI \tag{7}$$

The thermal resistance was used to evaluate PHP performance. The thermal resistance was determined by taking the difference between the evaporator and condenser temperatures divided by the difference in the power inputted and the heat loss (Eq. 8). This gave the thermal resistance of the PHP system, including the contributions of both conduction through the aluminum and the heat transfer due to the oscillating PHP flow.

$$R_{PHP} = \frac{(T_E - T_C)}{Q_{in} - Q_{loss}} \tag{8}$$

RESULTS

The objective of this research was to implement a PHP successfully into a flat plate for use in electronics cooling. The enhancement due to the PHP was determined by subtracting the heat loss to the environment and heat transfer through the aluminum plate from the power input.

Some lessons were learned in the construction of the PHP heat sink prototype. In the original heat sink design, the aluminum plate was 5mm thick; this resulted in a large conductive heat transfer that negatively affected the PHP's performance (as well as making it harder to determine the magnitude of the PHP-provided enhancement). It was also determined that a stronger clamping force than used initially was required to reduce thermal resistance between the PHP and the heating and cooling blocks. Finally, a good cooling block design is essential for heat removal from the condenser section of the PHP, especially at higher inputs. If the cooling block is undersized, then the PHP's power range will be severely limited.

Table 1 presents the results of the PHP performance when it is uncharged for use as a comparison to show how the PHP improves heat transfer.

Table 2 and 3 presents the steady-state performance values for all four operating conditions. The PHP provided significant heat transfer improvements over the aluminum plate alone. Uncharged, the PHP was able to transfer a maximum of 50 watts before the evaporator temperature reached a critical value (90°C) that would reduce a microprocessor's performance and lifespan. When charged, the PHP was able to maintain an operational temperature for a microprocessor even with significantly larger amount of input power. This shows that if it is charged, the PHP greatly improves the heat transfer over the aluminum plate alone. Power inputs were increased until the cooling bath capacity was reached and it was no longer maintainable at the desired condenser temperature.

Table 1: Results of operating the pulsating heat pipe uncharged (dry) for varying power input levels. The corresponding evaporator temperature is also presented.

	Evaporator Temperature (°C)	Thermal Resistance (K/W)
Power (W)	-	-
10	38.9	1.97
20	53.7	1.97
30	68.4	1.97
40	80.9	1.97
50	93.7	1.97

Table 2: Steady-state operation of the pulsating heat pipe when it is in the vertical orientation.

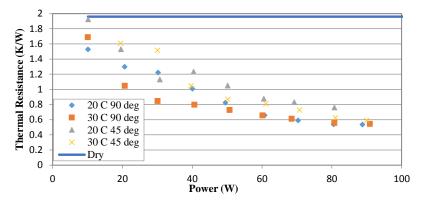|	Condenser Temperature			
	20° C	30° C	20° C	30° C
Power	Evaporator Temperature		Thermal Resistance (K/W)	
——— W ———	———°C ———		——— K/W ———	
10	33.4	39.7	1.53	1.69
20	41.7	44.6	1.30	1.05
30	48.6	49.6	1.22	0.85
40	53.0	55.6	1.01	0.80
50	55.4	61.7	0.83	0.73
60	55.9	63.8	0.66	0.66
70	57.3	65.9	0.59	0.61
80	59.7	70.1	0.54	0.56
90	63.9	71.8	0.54	0.54
100	68.8	74.7	0.49	0.53

The data is also shown in

Figure 6 to show more clearly the effects of inclination angle and condenser temperature on PHP performance. When the PHP is oriented vertically (90°) and the condenser temperatures are set to 20°C and 30°C the thermal resistances converge to nearly the same value as power is increased. Similarly, when the PHP is at a 45° angle with the same

evaporator temperatures the thermal resistances converge to a values slightly greater then recorded for the vertical inclination angle. This indicates that the thermal resistance may be more dependent on orientation than condenser temperature. This agrees with previous studies showing that thermal resistance decreases as power is increased and that the PHP performs better in the vertical orientation [9, 13, 14].

Table 3: Steady-state operation of the pulsating heat pipe when it is at a 45° orientation.

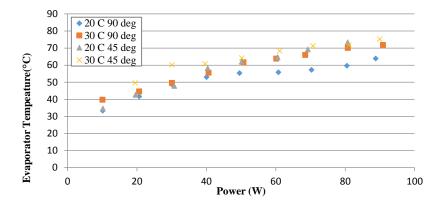|	Condenser Temperature			
	20° C	30° C	20° C	30° C
Power	Evaporator Temperature		Thermal Resistance (K/W)	
—— W ——	———————— °C ———————		——————— K/W ———	
10	34.6	-	1.93	-
20	42.7	49.6	1.53	1.61
30	47.9	60.1	1.13	1.52
40	58.2	60.8	1.23	1.05
50	62.2	64.2	1.05	0.87
60	64.7	68.4	0.88	0.81
70	69.2	71.3	0.83	0.73
80	73.5	71.7	0.76	0.63
90	-	75.2	-	0.59
100	-	80.2	-	0.59

As the heat input was increased, the thermal resistance for both condenser temperatures converged to approximately the same value. It should be noted, however, that in the intermediate power range, the thermal resistance was lowest in the vertical orientation for the 30°C evaporator temperature.

Figure 6: PHP thermal resistance performance for various power inputs, inclination angles, and condenser temperatures are all displayed in the graph above.

It can be seen in Figure 6 that when the evaporator temperature is 30°C and vertically oriented a lower thermal resistance is produced, it produces an evaporator temperature similar to that seen when the evaporator temperature is 20°C and oriented at 45°. The difference in performance was significant enough that the heater temperatures for the case with a 45° inclination angle and 20°C condenser temperature were similar to those for the vertical orientation and 30°C condenser temperature. In a study conducted by Hansen et al., it was concluded that operating the PHP with a warmer, condenser temperature could reduce evaporator temperature and improve performance [17]. The results of this study do not definitively support this claim. In the vertical orientation the 20°C condenser temperature had a lower thermal resistance, but in the 45° orientation the 30°C condenser temperature had the lower resistance. It is shown that the PHP performance is not significantly reduced by operating the condenser at a warmer temperature, indicating that performance may be relatively consistent over a wider range of condenser temperature.

It was observed that when the PHP was vertically oriented (90°) pulsations did not start until 30W. At this power input, pulsations were very inconsistent and temperature fluctuations in the evaporator section were large. As power was increased pulsation frequency increased, this resulted in smaller fluctuations in the evaporator. At the maximum input power, the pulsations were at such a high frequency that the evaporator temperature was nearly constant.

Figure 7: PHP evaporator temperature for various power inputs, inclination angles, and condenser temperatures are displayed in the graph above.

When the PHP was oriented at 45° up from horizontal, results similar to the vertical orientation (90°) were observed. As power increased, pulsation frequency increased resulting in a more constant evaporator temperature. The notable difference between the two orientations is that when pulsations begin at the 45° orientation, approximately 40-50W, pulsations are very cyclic. Indicating that the evaporator approaches an upper threshold temperature where pulsation begins. After a short period of pulsation, thus cooling the evaporator section, a lower threshold is reached stopping the pulsations. The evaporator section again heats up until the upper threshold temperature is reached and the process is repeated.

Comparing the results found here to a similar apparatus developed by Yang et al. [9] shows that the determined thermal resistances are comparable. The comparison also shows a need for a cooling mechanism redesign to increase the range that the PHP can be operated. In the studies by Yang et al. [9], performance of PHP was studied up to approximately 450W, whereas this study was only capable of reaching a maximum of 110W due to the limitations of the apparatus in removing heat from the condenser section.

CONCLUSIONS

A PHP was successfully integrated in a small-scale aluminum plate which could be used for electronic cooling applications. The PHP integration provided significant heat transfer

enhancement compared to the aluminum plate alone. Thermal resistance values were as low as 0.49 K/W and 0.53 K/W when the condenser temperature was set to 20°C and 30°C, respectively. When the PHP was tilted to 45° above horizontal the PHP had a resistance of 0.76 K/W and 0.59 K/W when the condenser was set 20°C and 30°C, respectively. Thermal resistance was much more dependent upon orientation then on condenser temperature. PHP performance could possibly be improved to better suit the thermal management needs of electronics through several modifications to this design. Because water was used, the channel sizing should be enlarged so the Bond number (currently 0.53) is in the middle of the acceptable range (0.49 to 3.39). This may help to induce pulsation at a lower power input. Another improvement would be to reduce the conductive heat transfer so that the heat transfer caused by the pulsation can better be determined. This could be done by reducing unnecessary material between channels or selecting a material with a low conductive value.

LIMITATIONS

It was observed that the cooling block was the limiting factor in the PHP overall heat transfer capacity. Cooling block design should be emphasized in future work to ensure the full potential of the PHP can be determined.

ACKNOWLEDGEMENTS

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Effects of Student Athletics on Academic Performance

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ABSTRACT

The purpose of this study is to examine the effects of involvement in athletics at the collegiate level at South Dakota State University. This paper seeks to determine if participation in collegiate athletics is beneficial to a person or if its disadvantages outweigh the advantages. Sixty-seven student-athletes completed a survey during October of 2013 to determine the effects that athletic involvement has had on SDSU's campus. This study found that participation in athletics is extremely beneficial. These athletes performed better in the classroom, developed impressive time management skills, felt motivated to complete their degree, were motivated to attend classes, and experienced a smoother transition into the college lifestyle.

INTRODUCTION

There are over 450,000 athletes competing at the collegiate level across 24 different sports in the United States (NCAA, 2012). Many children are coerced into sports as children, by their parents, to get involved and find a passion or hobby in life. But should parents be encouraging their children into a life full of sports or are the effects of sports too negative to keep pursuing? Many athletes aren't allowed the opportunity to continue their athletic endeavors at the collegiate level, but as stated above today there are almost 500,000 student athletes in the NCAA that have continued to pursue their athletic careers in college. The term "jock" is a well-known stereotype of athletes in high school and college. The term "jock" has negatively been associated with the average athlete who seems solely concerned

with athletics, but the name is living up to the academic ambitions of athletes today. One previous study by Pascarella, Bohr, Nora, and Terenzini (1995) found that collegiate athletes are indeed suffering in the classroom and in cognitive knowledge compared to their peers. On the contrary, studies are recognizing the positives of athletic involvement, such as increased time management, satisfaction with school, and acknowledgement that the positives outcomes may outweigh the negative outcomes (Maloney & McCormick, 1993; Byrd & Ross, 1991; Pascarella, Truckenmiller & Terenzini, 1999). The purpose of this study is to examine the effects of the involvement in athletics at the collegiate level at South Dakota State University.

REVIEW OF LITERATURE

Every athlete dreams of moving onto the professional level and getting paid to play the game that they love, but in reality a majority of the 450,000 NCAA student athletes will not continue onto the professional level. This is causing people to ponder if the sacrifice to the academic progress of athletes is worth the energy to continue playing sports for four more years in college. Many people argue that the academic performance of athletes is troubling considering that after sports they only have their education to fall back on and make a life out of that knowledge. In a study conducted by Pascarella et al. (1995), the results found compelling results about the cognitive developments of first year athletes. The study was conducted to determine the effects of college athletics on reading comprehension, math and critical thinking skills. There were 2,416 first year students who took part in the National Study of Student Learning survey, which is a longitudinal evaluation of the factors that affect learning and cognitive developments in college. They discovered that male athletes, in revenue sports such as football and basketball, suffered in reading comprehension and math. They found that these revenue sport athletes struggled compared to non- athletes, and male athletes in other sports tested the same as non-athletes in reading comprehension and math. On the contrary, female athletes lagged behind their peers in reading comprehension. Both male and female athletes fell behind non-student athletes in critical thinking skills such as open mindedness, maturity and inquisitiveness (Pascarella et al, 1995). These statistics confirm that some athletes are lagging behind their peers, but have led researchers

to believe that revenue sports may be the real source of the low academic progress of athletes.

The hours of practice and preparation for game day undoubtedly take athletes away from their studies. Maloney and McCormick (1993) conducted a study at Clemson University of 595 student athletes in determination of finding the effect of athletics on academic success. They found that academically, athletes do three-tenths of a grade point worse than regular students in three out of 10 classes. They also discovered athletes in revenue sports are lagging behind their peers. Athletes in football and basketball do one-tenth of a grade point worse than their fellow student athletes (Maloney & McCormick, 1993). Concerns for revenue sports are extreme with suggestions that these major sports do not allow time for their athletes to be students. Some people are even voicing their opinion that these athletes are employees of the athletic department (Feezell, 2001).

The concern over student athlete success has culminated into millions of dollars being spent at universities for academic support of their athletes along with new NCAA regulations over academic affairs, hours spent practicing, and days off. Burns, Jasinski, Dunn and Fletcher (2013) conducted a survey focused on determining the effects of academic support services on career decision-making skills for athletes. They conducted a study of 158 Division 1 student athletes from 11 different universities. All student athletes in this study were required to attend academic support programs at their universities during their freshman and sophomore years. All programs were based on the NCAA Challenging Athlete's Minds for Personal Success (CHAMPS) program and contained an online vocational assessment, access to career counselors, and workshops on career planning, resume writing and internships. The results were calculated by surveys that were distributed by coaches to the specific athletes. Satisfaction with academic support services was measured with the Reimer and Chelladurai's Athlete Satisfaction Questionnaire whereas the Betz, Klein and Taylor's career decision-making self-efficacy scale was used to measure confidence in making career decisions. The results showed a positive correlation between people who believed academic support services were helpful with confidence in career direction. These CHAMP programs make people feel more confident about their life skills, and certain of their career decisions through resume development and experience in that specific field through internships (Burns et al, 2013). Although these academic support

services are an expensive commodity for universities, it is necessary to provide designated people to work with athletes. This will balance both athletics and academics to create a situation that helps athletes succeed in both fields.

On the other hand, many people are firm believers that the positives of athletic participation outweigh the negatives. Studies have shown that participation has a positive impact on learning and development (Bonfiglio, 2011). A study conducted by Byrd and Ross (1991) focused on the influence of athletic participation at the junior high level and showed that, even at a young age, athletics is motivating student athletes in the classroom. Their study was conducted in a rural county in Tennessee and is based off the responses of 379 students with an intermixed number of athletes and non-athletes. These students attended one of two schools in this area and the study consisted of 284 non-athletes and 95 athletes. The study's results showed that 70% of people agreed that being an athlete motivated them to attend school regularly. This study also found that 71% said participation led to better time management. Competing at the collegiate level results in substantial missed class time, but when they are not traveling, athletes are attending classes to ultimately stay eligible to continue playing the sport that they love. Athletic involvement promotes more efficient use of time and higher motivation to excel at different school endeavors (Byrd & Ross, 1991). Time management skills are important for future jobs and endeavors. Competing at the NCAA level for four years and still managing to graduate prepares athletes with the skills to help them be successful in life. Although some athletes stumble academically, parents still continue to see athletics as a positive involvement for their children. Byrd and Ross (1991) conducted a second survey of the parents, principals, teachers and coaches of the 379 athletes of the Tennessee students and what they believe are the influences of participation in sports. The study found that the top five factors as to why parents chose to enroll their children in sports are: enhancing school identity, attracting community support, decreasing racial prejudice, promoting physical fitness and wholesome participation, and increasing revenue. Through sports involvement these athletes get to meet new people from differing backgrounds, become involved with their community, create a sense of pride for their school, and lead physically acceptable lifestyles (Byrd & Ross, 1991).

Studies by Pascarella, Truckenmiller, Nora and Terenzini (1999) and Pascarella, Bohr, Nora, and Terenzini (1995) focus on what the positive impacts of athletics have on non-

cognitive development. Using the national sample from the Cooperative Institutional Research Program to help with the study, Pascarella et al (1999) found positive correlations with the satisfaction and the overall college experience, motivation to complete degree, bachelor's degree completion, and persistence in college. Being a part of athletics kept these student athletes motivated to continue their pursuit to attain their degree, receive good grades to stay eligible and meet graduation requirements. These statistics shed light on the success of upper level college students, but what is the impact for first year college students on getting acquainted with the university? Pascarella's 1995 study focused on the study of 23 two-year and four-year colleges in sixteen states around the country. This study was conducted to look at the positive outcomes for first year students from participation in collegiate athletics. The study found that participation in intercollegiate sports positively influenced gains in success during their first year of college in regards to feeling at home at the university and success in classes (Pascarella et al, 1995).

The results from these studies showed the varying research depicts both the positives and negatives to involvement in collegiate athletics. The negatives to involvement in athletics are centered on the academic and cognitive losses of collegiate athletes. Pascarella et al (1995) found that first year student-athletes lagged behind their peers in the cognitive development categories of reading comprehension, math, and critical thinking skills (Pascarella et al, 1995). Maloney and McCormick's study discovered that athletes do three-tenths of a grade point worse than regular students in three out of ten classes (Maloney & McCormick, 1993). Student athletes struggle with life outside of the competition field in terms of defining their life skills and careers without their athletic capabilities. Burns et al (2013) revealed that student-athletes who believed academic support systems were helpful and attended CHAMPS events felt more confident in their career direction and life skills. On the contrary, many people believe that involvement in sports is irreplaceable. Byrd and Ross found that being a part of athletics motivated students to attend class regularly and participation also led to better time management. Another study by these two examined why parents enroll their children in athletic programs. The results showed that parents believe that athletics enhances school identity, decreases racial prejudice, increases revenue, and promotes physical fitness and wholesome participation. Many of the negatives about collegiate athletic involvement center on academics, but Pascarella, Truckenmiller, Nora and Terenzini fire back by finding that athletes have great satisfaction with their

college experience, motivation to complete their degree, bachelor's degree completion, and persistence in college (Pascarella et al, 1999). Those four conducted another study that revealed positive correlations between athletic involvement and feeling at home with the university and success overall in classes. Ultimately there will never be an answer that satisfies every person's opinions and attitudes, but these researchers are providing the public with more information to make an informed decision on collegiate athletic involvement and if it is a good choice in their lives.

METHODS

Research was conducted through a 16-question survey and 70 copies were made to hand out to student-athletes on the campus of South Dakota State University in Brookings, South Dakota. On October 16, 2013, 27 surveys were handed out at a Student Athlete Advisory Committee meeting and 21 of the surveys were distributed at a Fellowship of Christian Athletes gathering. Within the time span of October 17 and 18 another 22 were distributed to members of the Men's and Women's Swim and Dive teams. All participants were very considerate and spared three minutes out of their time to complete the survey. The response rate of the survey was a remarkable 100%, but three surveys were deemed unusable because questions remained unanswered. As a result, only 67 surveys were used in this study.

The first two questions of the survey were general, demographic questions used to identify the characteristics of the group as a whole. These two demographic questions were inquires about gender and education status. The 14 questions that followed pertain directly to the research question about the effects of participation in collegiate athletics and all use some variety of the Likert scale to determine the constituent's responses. The first question establishes if time management skills have been affected by participant's involvement in athletics. The following two questions exist to compare the amount of time that athletes devote to athletic commitments and academics. The next two questions seek to determine athlete's beliefs about their grades and how important they are to them. These two questions seek to determine the standing of their grades without involvement in athletics and if they would continue to participate in athletics if this participation resulted in worse grades than normal students. The following three questions pertain to academic support

services utilized by athletes at the Dykhouse student athlete center. These questions seek to determine if these services are helpful, if people are attending the events, and if event participation is having the desired positive affect on athletes' life skills and career direction. The next question focuses on the persons motivation to attend classes and if attendance is impacted by involvement in athletics. The following three questions focus on the impact of athletic involvement on the individual's life and college transition. The first question focuses on the effect of athletic involvement on the individual's life, the second focuses on if this involvement made their college transition easier, and the last of the three seeks to determine if their participation in athletics has been irreplaceable. The next question requests the student-athlete state their current grade point average. The final question pertains to graduation requirements and wishes to grasp if involvement in sports, along with NCAA regulations on credit totals for eligibility, has motivated athletes to degree completion and persistence toward graduation.
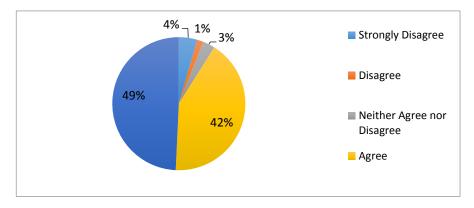
RESULTS

The results were collected from 67 student-athletes on the campus of South Dakota State University in Brookings, SD. They were obtained from 27 individuals at a Student Athlete Advisory Committee meeting, 21 individuals at a Fellowship of Christian Athletes gathering, and 22 individuals on the Swim and Dive team. The results are presented in 14 charts below.

Table 1: Demographics of survey participants including gender and year in school.

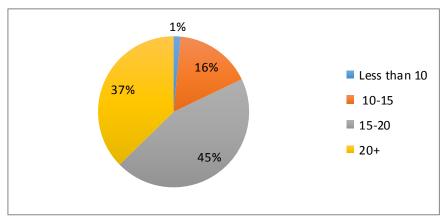| Gender	Frequency	Percentage
Male	23	34
Female	44	66
Education		
Freshman	13	20
Sophomore	15	22
Junior	20	30
Senior+	19	28
Total	67	

Table 1 displays the results to the two demographic questions pertaining to the survey's participants. The survey's partakers were two-thirds female at 44 people, and one-third male at 23 people. The educational ranks of the individuals varied with 13 participants being freshman, 15 sophomores, 20 were juniors, and 19 characterized themselves as seniors and anything above.

Figure 1: Percentages at which SDSU's athletes agree that being a student athlete has helped them develop better time management skills.

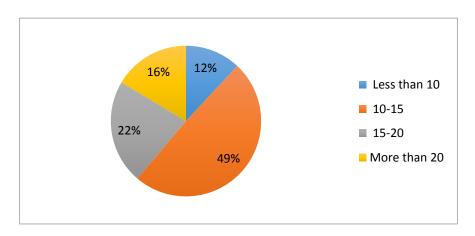Sixty-seven student athletes were asked if they agreed or disagreed on whether their involvement in sports helped them develop better time management skills. The results revealed that 33 people "strongly agree" that athletics improves their time management skills, 28 "agree" that it helps them, two neither "agree nor disagree", one "disagree", and three "strongly disagree." The results are shown in Figure 1.

Figure 2: Percentage of hours that SDSU athletes feel that they devote to their athletic commitments.

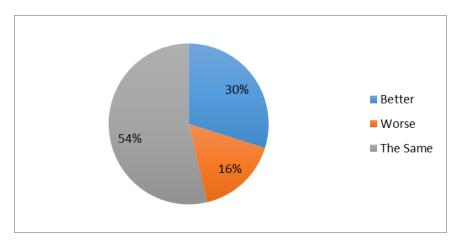The student-athletes were asked to specify the approximate time per week they devote to their athletic activities such as practice, games, film and training room needs per week (Figure 2). One person spends "less than ten hours" between commitments, 11 devote "10-15," 30 expend "15-20," and 25 spend "20+" between all athletic commitments.

Figure 3: Percentage of SDSU athlete's time that is devoted to academic work.
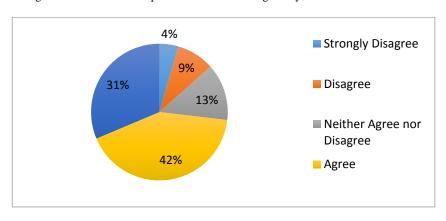
On the contrary, the student athletes were also asked to state how many hours they devote to academics per week. Eight athletes spend "less than ten" hours on homework, 33 devote"10-15," 15 expend "15-20," and 11 devote "20+" to academic work.

Figure 4: Responses from student-athletes to the following question: Would your grades be better, worse, or the same if you were not a student athlete?
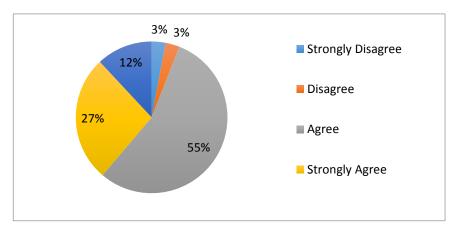
The participants of this survey were asked to state whether they believe their grades would be "better," "worse," or "the same" if they were not a student-athlete. Twenty athletes believed their grades would be "better", eleven "worse," and 36 stated their grades would "stay the same."

Figure 5: Percentage of athletes that agree that they would still choose to participate in collegiate athletics if it were proved that athletics negatively affected academics.
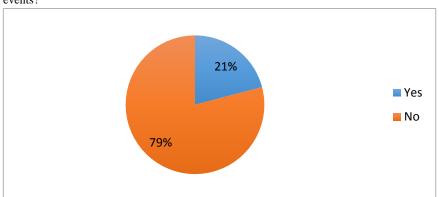
When asked if they would continue their athletic endeavors if it was proven that athletics hindered academics, many agreed it wouldn't change anything. Three people "strongly disagree," and six "disagree" believing involvement would not be worth it. Nine "neither agreed nor disagreed," 28 people "agreed," and 21"strongly agree" that they would continue their athletic ambitions no matter the circumstances.

Figure 6. Responses of athletes from the following question: Have the academic support services at Dykhouse Student Athlete Center helped you succeed?
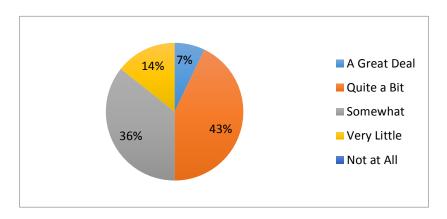
The athletes surveyed were asked if the academic services at Dykhouse Student Athlete Center helped them succeed expressed by "strongly disagree," "disagree," "agree," "strongly agree," or "have not utilized these services." Two people "strongly disagree," two people "disagree," 37 "agree," eighteen "strongly agree," and eight people "have not utilized these services."
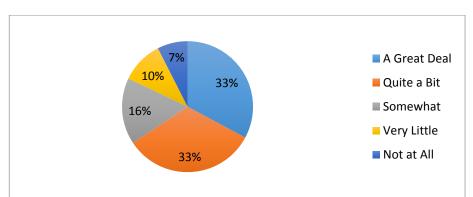
Figure 7: Student-athletes' responses to the question: Have you attended any CHAMP events?

When asked if they had attended any of the CHAMP events on campus, 14 said they had attended events, and 53 stated they had not attended any of these events.

Figure 8: Students' response to the question 'Were CHAMP events beneficial towards identifying life skills and determining your future career?'

The 14 people were then asked how beneficial these CHAMP events were towards determining career direction and identifying life skills. One person said these events were beneficial "a great deal," six people stated they helped "quite a bit," five people said they helped "somewhat," two people thought they helped "very little," and zero people believed they were unbeneficial.

Figure 9: How athletic involvement affected students' motivation to attend classes regularly.

The group of survey participants were asked to define the effect that athletics has on their motivation to attend classes as "a great deal," "quite a bit," "somewhat," "very little," or "not at all." There were 22 participants that responded with "a great deal," 22 "quite a bit," 11 "somewhat," seven "very little," and five "not at all."
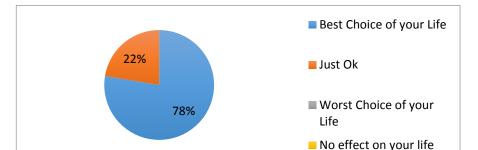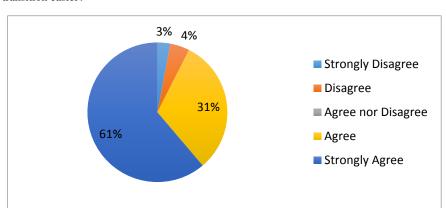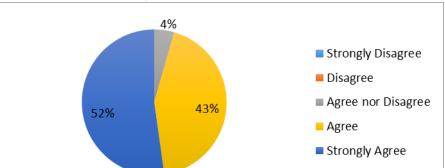
Figure 10: How students describe the effect of athletic involvement in their life.

The impact of athletics in their lives was defined by "best choice of your life," "just ok," "worst choice of your life," or "no effect on your life." As shown in Figure 10, 52 people answered that athletics was the "best choice of their lives," 15 "just ok," zero "worst choice of your life," and zero "no effect on your life."

Figure 11: Results of the question: Do you believe athletic involvement made your college transition easier?

Their involvement in athletics in regards to making the college transition easier was measured by "strongly disagree," "disagree," "agree nor disagree," "agree," or "strongly agree." Two people "strongly disagreed," three people "disagreed," zero people "agree nor disagree," 21 "agree," and 41 "strongly agree."
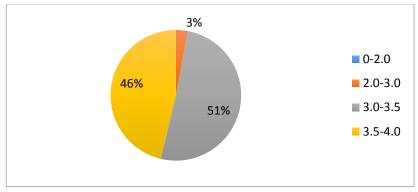
Figure 12: Percentage of SDSU athletes who believe that the benefits of athletic involvement far exceed the negatives.

The sixty-seven athletes were asked to agree or disagree with whether they believe their participation in sports is irreplaceable and the benefits of involvement far exceed any
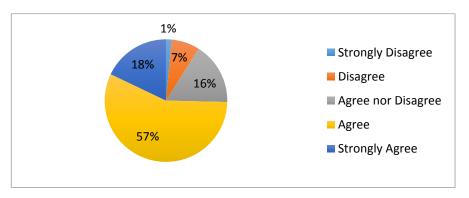
negatives. Zero athletes "strongly disagree" or "disagree," three "agree nor disagree," 29 "agree," and 35 "strongly agree."

Figure 13: Percentage of GPAs among the students.

When asked about their current grade point average, zero answered "0-2.0," two "2.0-3.0," 34 "3.0-3.5," and 31 "3.5-4.0."

Figure 14: Feelings athletes had about athletic involvement motivating them toward credit completion and persistence towards graduation.

The student-athletes were asked if their involvement in sports, and NCAA regulations on credit totals for eligibility, had motivated them toward grade completion and persistence towards graduation defined by "strongly disagree," "disagree," "agree nor disagree," "agree," or "strongly agree." Of the 67 participants, one responded with "strongly disagree," five "disagree," 11 "agree nor disagree," 38 "agree," and 12 "strongly agree".

DISCUSSION

Many different conclusions were drawn between the literature and the survey results that were found on the campus of South Dakota State University. The purpose of this paper is to examine the effects of the involvement in athletics at the collegiate level at South Dakota State University. The results were conducted in attempts to determine the positives and negatives of involvement in athletics from the view of the student athlete. For the most part, results from SDSU student athletes agreed with the scholarly research that was cited in the literature review.

One contradicting opinion involved the research of Maloney and McCormick. They found that athletes do three-tenths of a grade point worse than regular students every semester (Maloney, 1993). At South Dakota State University, this survey found that athletes do better in school than their peers. The average grade point of non-athletes at SDSU is 2.75. Of the 70 people polled for this study, only three percent were below a 3.0 GPA and none of the athletes went below 2.5. These statistics vary by college and division, but these results show the dedication that the SDSU Athletic Department has towards the students first and foremost.

Research indicates that there is a positive correlation between satisfaction with academic support services and confidence in career direction and identification of life skills (Burns et al, 2013). At South Dakota State University there is team of professionals who are specifically employed to assist student athletes at the Dykhouse Student Athlete Center. Along with their expertise, these people provide workshops, called CHAMP events, to make student athletes more prepared for life after athletics in regards to life skills and career path. The results of the survey showed that 79 percent of people state that academic services at the Dykhouse Student Athlete Center have helped them succeed. Only 14 of the 70 people attended a CHAMP event, and 12 found that these services were somewhat helpful in determining their life skills and career direction. There needs to be more participation in CHAMP events for any conclusion to be made about the influence of CHAMP events in the lives of student athletes at South Dakota State University (Burns et al, 2013).

Byrd and Ross' (1991) research suggests that participation in athletics is motivating student athletes in the classroom in terms of better time management and motivation to attend classes. Of the 22 people polled, they said their involvement in athletics has motivated them to attend class "a great deal," and 22 people answered "quite a bit." Their time management skills were also affected with 33 people stating they "strongly agree," and 28 asserting they "agree" that athletics has helped them develop better time management skills. Therefore only 6 out of 70 people believed athletics did not improve their time management skills. These results are consistent with research conducted by Byrd and Ross and demonstrate some of the positives that result from involvement in athletics (Byrd & Ross, 1991).

Pascarella et al (1999) found positive correlations regarding involvement in athletics and satisfaction with the overall college experience, motivation to complete degree, bachelor's degree completion, and persistence in college. The results of this survey were congruent with their research findings. Thirty-eight people "agree" and 12 "strongly agree" that their involvement in sports has motivated them toward grade completion and persistence toward graduation. When these 70 athletes were asked to describe the effect of athletic involvement in their lives, 52 people answered "best choice of their life." The love for the game is propelling these athletes to graduate while making their college experience memorable along the way. Evidence was also found from Pascarella et al to suggest that participation in athletics influenced positive gains during a student athlete's first year in college. On SDSU's campus, 41 people "strongly agree," and 21 "agree" that participation in athletics made their college transition easier. Both studies that Pascarella et al conducted were consistent with the research conducted of student athletes on this campus. The results from this study conducted on South Dakota State's campus challenge the negative views associated with participation in athletics (Pascarella et al, 1999).

LIMITATIONS

There are several limitations to the study conducted about the effects of participation in athletics at the collegiate level at SDSU. Seventy people completed surveys for this assignment, but there are more than 400 student athletes at SDSU. Surveying a more complete number of people would lead to more accurate results for this particular

university. In addition, time was a limitation for this study. A more extensive study could be conducted if there was more time given to the assignment. Another limitation is that only athletes at South Dakota State were polled. Polling athletes at other universities would provide insight into how other universities function in regards to athletic and academic achievements. There are significant differences between universities and polling several campuses would create a more uniform base of answers based off athletes across the United States. The last limitation is the variety of athletes polled. A more accurate pool of people could be utilized by receiving a specific response rate from every sport. In conducting this survey, sports were most likely left out and not included in the results. For future studies, it would be important to spend a more extensive period of time on the study. Surveying people from different universities, in different divisions of athletics, across a wide range of sports, will provide a stronger response field to analyze the differences between literature research and survey responses.

ACKNOWLEDGEMENTS

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APPENDIX

Student Athlete Survey

Hello! My name is Nicole Grimit and I am a junior here at South Dakota State University and I also am a member on the Women's Swim Team. I am enlisting your help in completing this survey for my Consumer Affairs class. The purpose of this study is to examine the effects of the involvement in athletics at the collegiate level at South Dakota State University.

This information will be used solely for this study and for my research paper in Work Family Interface, CA 340. Your answers are entirely confidential and will not be reported back to your coach or the athletic department. Thank you for taking a few minutes out of your busy athletic schedules to help me conduct my study. If you have any inquiries about this survey you may contact Dr. Cho or myself at: Soohyun.cho@sdstate.edu or nicole.grimit@jacks.sdstate.edu

Please circle the answer that best fits you:

1: What is your gender?

      A.   Male

      B.   Female

2: What year in school are you?

      A.   Freshman

      B.   Sophomore

      C.   Junior

      D.   Senior+

3: Has Athletics helped you develop better time management skills?

      A.   Strongly disagree

      B.   Disagree

      C.   Neither Agree nor Disagree

      D.   Agree

      E.   Strongly Agree

4: Approximately how many hours per week do you spend between all athletic commitments (film, practice, training room, etc)?

      A.   Less than 10 hours

      B.   10-15 hours

      C.   15-20 hours

      D.   More than 20 hours

5: Approximately how many hours per week do you devote to schoolwork?

      A.   Less than 10 hours

      B.   10-15 hours

      C.   15-20 hours

      D.   More than 20 hours

6: Do you believe your grades would be _____ if you were not a student athlete?

      A.   Better

      B.   Worse

      C.   The Same

7: If studies proved without a doubt that athletics negatively affected academics, would you still choose to compete at the collegiate level?

      A.   Strongly Disagree

      B.   Disagree

      C.   Neither Agree nor Disagree

      D.   Agree

      E.   Strongly Agree

8: Have the academic support services at Dykhouse Student Athlete Center helped you succeed?

      A.   Strongly Disagree

      B.   Disagree

      C.   Agree

      D.   Strongly Agree

      E.   Have not utilized these services

9: If you have used these academic services, have you attended any of the CHAMP events?

      A.   Yes

B.   No

10: If you have attended any of these CHAMP events, how beneficial would you say that they were toward identifying your life skills and determining your career direction?

    A.   A Great Deal

    B.   Quite a Bit

    C.   Somewhat

    D.   Very Little

    E.   Not at All

11: What effect does your involvement in athletics have on your motivation to attend classes?

    A.   A Great Deal

    B.   Quite a Bit

    C.   Somewhat

    D.   Very Little

    E.   Not at All

12: How would you describe the effect of athletic involvement on your life?

    A.   Best Choice of your Life

    B.   Just Ok

    C.   Worst Choice of your Life

    D.   No effect on your life

13: Do you believe that your athletic involvement made your college transition easier?

    A.   Strongly Disagree

    B.   Disagree

    C.   Agree nor Disagree

    D.   Agree

    E.   Strongly Agree

14: Do you believe that your participation in sports is irreplaceable and the benefits of involvement in athletics far exceed any negatives?

    A.   Strongly Disagree

    B.   Disagree

    C.   Agree nor Disagree

    D.   Agree

    E.   Strongly Agree

15: What is your current GPA?

    A.   0-2.0

    B.   2.0-3.0

    C.   3.0-3.5

    D.   3.5-4.0

16: Has your involvement in sports and the NCAA regulations on credit totals for eligibility motivated you toward degree completion and persistence towards graduation?

    A.   Strongly Disagree

    B.   Disagree

    C.   Agree nor Disagree

    D.   Agree

    E.   Strongly Agree

THANK YOU! HAVE A GREAT DAY ☺

Testing the Delivery of an Interactive Second Grade Nutrition Education Curriculum

Authors: Kaitlyn Hemmingson, Marie Ankeny, Jessica Becker, Krista Creager, Chris Josko, Abby Luitjens

Faculty Sponsor: Shelly Brandenburger, MS, RD, DC, PhD(c).

Department: Health and Nutritional Sciences

ABSTRACT

Childhood obesity rates in the United States are alarming. Interventions incorporating nutrition education and physical activity are important for initiating behavior changes that may reduce the risk of childhood obesity and future health complications. The availability of nutrition curriculum for use in a second grade audience is limited. For this project, a nutrition education curriculum for second grade students was developed and tested over a two-week period in the fall of 2013. Six second grade classrooms (N=118) received four 20-minute interactive nutrition lessons. Lesson topics included: MyPlate, Handy Portions, Sugar Shockers, and MyTray. Pre and post assessments of nutrition knowledge were used to determine the effectiveness of the nutrition education. Overall, there was an increase in the number of correct survey responses recorded following the nutrition education. By category, there were increases in the students' ability to identify healthy snacks, grains, dairy products, and protein sources, but not fruits and vegetables. Further development and testing of innovative nutrition education curriculum for the second grade audience is an important step in establishing the knowledge to influence lifelong behavior changes that could reduce future risk of obesity.

INTRODUCTION

Childhood obesity is a preventable condition that affects around 20% of children ages 6-11 in the United States.[1] Obese children are more likely to have high blood pressure, high

cholesterol,[2] impaired glucose tolerance, insulin resistance, type 2 diabetes,[3] sleep apnea, asthma,[4,5] fatty liver disease, gallstones, gastro-esophageal reflux,[3,4] and social and psychological problems.[3,6,7] Childhood obesity is especially alarming due to the fact that obese children with at least one obese parent are up to 79% more likely to be obese as an adult.[8] According to the Centers for Disease Control and Prevention, childhood obesity is a result of over consumption of energy and lack of physical activity.[9]

In a study by Cardoso da Silveira et al., researchers found that school-based nutrition education is effective in reducing the body mass index of children and adolescents, regardless of the intervention components.[10] Previous childhood obesity interventions tend to focus on two preventable lifestyle factors that have been shown to contribute to obesity: excessive food intake and low levels of physical activity. Nutrition education interventions have been developed over the years to increase awareness of healthy and appropriate food intake. Although there are many interventions available for pre-schoolers[11] and those above third grade,[10] few childhood nutrition interventions have been developed and validated for use among a second grade audience. Second grade students are in the 8 to 9-year-old age range, which is a prime age for learning about the importance of nutrition for their life long well-being. In a country where most people get their nutrition information from the media,[12] it is important to capitalize on opportunities to teach reliable nutrition education. Therefore, the objective of this study was to develop, implement, and test the effectiveness of a nutrition education program specifically designed for a second grade audience.

METHODS

The South Dakota State University Institutional Review Board approved this study. In collaboration with a South Dakota State University nutrition instructor, seven senior-level university students developed a nutrition education program to be delivered and tested for effectiveness in second grade elementary students. The program was implemented in six second-grade classrooms (N-118) over the course of two weeks during regular classroom hours. The program was broken into a series of 20-minute interactive question-answer lessons. The topics covered include: introduction to MyPlate (day one), handy portions (day two), sugar shockers (day three), and MyTray (day four).

In the first lesson, MyPlate was introduced to the students and foods from each food group were identified. The students classified various foods into the five food groups of MyPlate: fruits, vegetables, grains, liquid dairy, and protein. The second lesson covered portion control. Students were taught how to measure portions using their hands so they could learn the correct amount of various foods to eat. On the third day, a visual demonstration displayed the amount of sugar in commonly consumed sugar-sweetened beverages. Sugar cubes, in plastic bags, were held up alongside various drinks; students were asked to correctly match the amount of sugar with the corresponding beverage. Along with the visual demonstration, two short videos [13] addressing the consumption of sugary beverages in the United States were shown. On the final day, the students applied their knowledge gained over the course of the curriculum to create their own healthy lunch. Using trays from the lunchroom, the students walked around the classroom and selected pictures of healthy and unhealthy food options to create a balanced meal. The students were encouraged to create a meal they would actually eat. The students then "checked out" with one of the nutrition education instructors to ensure a food from each food group was chosen. Prizes were distributed during the lessons as an incentive for participation in the discussions.

An Expanded Family Nutrition Education Program (EFNEP) assessment tool that had been used in several other studies to determine nutrition knowledge among kindergarten to second graders [14] was used to evaluate the effectiveness of the program. The paper survey was delivered both prior to and following the delivery of the lessons. This 10-question, picture based tool (Appendix A) was adapted from its original form to keep costs of delivery within budget. The tool focused on broad nutrition questions, but was primarily intended to assess the ability of students to visually identify particular food groups. Only questions related to the education provided were evaluated to determine efficacy of the program. Statistical analysis of results was conducted using Microsoft Excel.

RESULTS

Overall, six out of 10 questions were chosen for analysis based on correspondence to the delivered nutrition education. Questions regarding personal hygiene and exercise were not covered during the lessons and, therefore, were not included in the analysis.

Table 1: The changes in responses from the pre and post nutrition assessment survey (N=118) can easily be seen in the table below.

Food Group	Desired Change		No Change		Undesired Change	
	Increase in correct responses		No change in correct responses		Decrease in correct responses	
	--- n ---	--- % ---	--- n ---	--- % ---	--- n ---	--- % ---
Q.1 Healthy Snacks	10	8	102	86	6	5
Q.4 Vegetable Group	6	5	102	86	10	8
Q.5 Fruit Group	11	9	94	80	13	11
Q.6 Grain Group	55	47	52	44	11	9
Q.7 Dairy Group	23	19	77	65	18	15
Q.8 Protein Group	51	43	55	47	12	10

Overall, there was an increase in the number of correct responses recorded from pre to post assessments, indicating an overall improvement in nutrition knowledge (Table 1). There were also slight improvements in the ability of students to identify healthy snacks; however, a majority of students had no change in the amount of correct versus incorrect responses. Surprisingly, there was a slight decrease in correct responses from the pre to post assessments for the identification of foods in both the vegetable group and the fruit group. Positive improvements were seen on questions regarding protein, dairy, and grain identification. There was a 47% increase in the number of correct responses for identification of grains and only a 9% decrease in the number of correct responses. There was a 19% increase in correct answers to the dairy identification question and a 15% decrease in correct responses. Finally, a significant improvement was shown for answering the protein identification question correctly from pre to post surveys (43% increase in correct student responses).

DISCUSSION & CONCLUSION

The objective of this study was to develop and implement a second grade nutrition education program and to test the effectiveness of the program in changing basic nutrition knowledge. There is sufficient evidence to support the theory that the school environment is a good location for the delivery of nutrition education.[15, 16, 17] Following the delivery of nutrition education, students displayed significant improvement in protein identification and moderate improvement in both dairy and grain identification, suggesting that the program was effective for these categories. Also, there was an overall increase in the number of correct responses to the survey, suggesting that the intervention was beneficial. Decreases in nutrition knowledge can be explained by non-consecutive education days, the overwhelming amount of education delivered, and inconsistencies in delivery methods due to the variety of university students teaching the curriculum. Enhancement of nutrition education by teachers in between the delivered nutrition lessons was not measured; however, additional education may have influenced the results.

In the past, nutrition education programs for elementary students have been shown to be a promising tool for weight reduction.[10] Even though the delivered nutrition education program was effective for increasing the recognition of certain healthy food categories,

more reinforcement of these messages from a variety of sources is recommended for establishing long-term behavior change that results in obesity reduction. Future nutrition education recommendations for the second grade audience include 1) choose consecutive days of the week to deliver nutrition education, 2) suggest ways for teachers to continue integrating the delivered nutrition messages throughout activities during the school year, 3) ensure consistent delivery methods of nutrition education, making an effort to have the same educators delivering the lessons each day, and 4) deliver a follow-up survey to determine students' long-term recall. Combining nutrition education with other tools may also be a way of increasing behavior change among the elementary audience. Other studies have found that positive outcomes in nutrition education programs have been attributed to the incorporation of parents in the nutrition education intervention.[14, 16] Involvement of school faculty members to support nutrition messages within the school meal program has also been cited as contributing to positive outcomes in the nutrition education program. [18] Modification of the school environment including incorporation of competitive food policy, psychosocial support, and food service, has been considered a top priority for shaping student health behavior.[17] Technology-driven education has also been suggested for improving adolescent nutrition messages.[19] Additionally, the use of school gardens combined with nutrition education has been shown to increase vegetable consumption among second grade students, [20] as well as increasing overall well-being and strengthening the school environment for positive youth development.[21] Incorporating any or all of these ideas into school-based nutrition education should be considered for impacting overall behavior change among elementary students.

Delivery of school-based nutrition education has the potential to help prevent excessive weight gain and future related complications. The school provides a great environment for the early establishment of nutrition education curriculum for a second grade audience. Effective and lasting nutrition education curriculum for the second grade audience is limited. Continued development, publication, distribution, and testing of nutrition education for the second grade audience will enable researchers and educators to help advance this limited, but growing field of interest.

LIMITATIONS

Some of the limitations of the delivery of this nutrition education are beyond the control of the researchers. Limitations include scheduling conflicts, forcing nonconsecutive delivery of nutrition lessons, possible lack of reinforcement of messages beyond the lessons delivered, and limited time slots available to deliver the planned nutrition education. Variations in teaching methods of the nutrition educators could have also caused inconsistent delivery of messages. Continued collaboration with school leaders and faculty may help overcome some of these barriers in future programming. More extensive training in the delivery of nutrition lessons may help attenuate differences among educators.

ACKNOWLEDGEMENTS

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ID_____

Pre_____ Post_____

APPENDIX A: Youth Knowledge Evaluation

1. Circle the healthy snacks.

APPLE

CAKE

CARROTS

BANANAS

GRAPES

FRENCH FRIES

2. Circle when you should you wash your hands before eating.
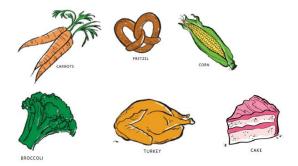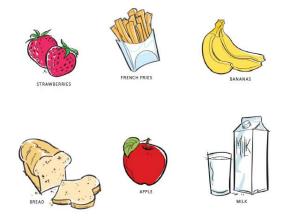
3. Circle the pictures that show physical activities.
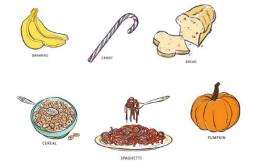
4.   Circle foods from the vegetable group.
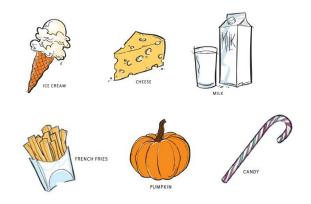
5.   Circle foods from the fruit group.

6.   Circle foods from the grains group.

7.   Circle foods from the dairy group.

8. Circle foods from the protein group.

9.At your home, do you have vegetables to eat?
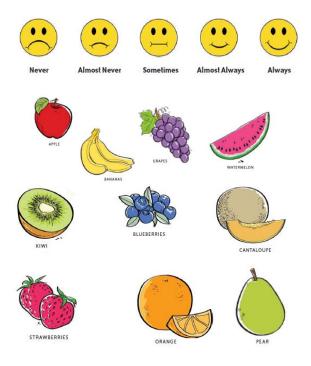
10. At your home, do you have fruits to eat?

The Mathematics of Spot It

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ABSTRACT

Spot It™ is a fun, fast paced game for people of all ages. The game appears to have a rich mathematical structure, which we investigated, using combinatorial analysis. We constructed some similar *Spot It* type games with a different number of cards, and displayed that some games are impossible to complete. In particular, the original *Spot It* game has eight objects on each card; however, it is impossible to construct a complete game (a game in which every object appears with every other object) in which every card has seven objects. We have investigated the mathematics behind the game.
Keywords: mathematics, combinatorics.

INTRODUCTION

Spot It, created by Blue Orange Games, is a game for two to eight players, ages seven and up. The object of the game is to find the matching symbol between two cards the fastest. *Spot It* has a deck of fifty-five cards, each with eight objects, and every pair of cards has only one matching symbol.

In Figure 1 there are three cards from the actual *Spot It* game with eight objects on each of the three cards. A player is to find the matching objects between the cards.

Figure 8: These are three cards from the Spot It game.

The matching symbols among the 3 card are illustrated in Figure 2.
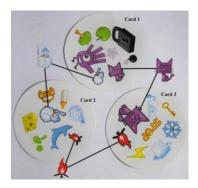
Figure 9: These are the original three cards with the matching objects highlighted.

Spot It is, in a sense, incomplete, because there are two cards that could be added to the deck. Specifically one of the cards would be created with the cactus, daisy, dinosaur, ice cube, man, maple leaf, question mark, and snow man symbols. The other card would contain a dog, exclamation mark, eye, lady bug, light bulb, skull and cross bone, snow man, and the word "stop". The matching symbol between these two cards would be the snow man. I tried contacting the Blue and Orange Games company to ask why they chose not to include these final two cards in the game; however, they did not respond. From now on in the paper we will assume the *Spot It* game has the two missing cards for a total of fifty-seven.

PROCEDURES AND ASSUMPTIONS

Some explanation of terminology is necessary in order to develop the mathematics behind *Spot It*. A symmetric game is a game in which every object appears the same amount of times. A complete game is when every object appears the same number of times, but also appears exactly once with every other object on some card. An example of a symmetric game that is not complete could be constructed as follows. Let the objects be denoted by the letters A, B, C, D, E, and F. Then the following four cards, each with three objects, form a symmetric (but not complete) *Spot It* game:

$$ABC \qquad ADE \qquad BDF \qquad CEF.$$

Each letter appears twice so the game is symmetric, but it is not complete. For example, A does not appear with F. *Spot It* would be a complete game, since it has each object appearing eight times and each object appears with every other object. This work will focus more on complete games.

Necessary variable are defined as:

N = the number of cards

r = the number of objects per card

k = the number of times each object appears

t = the number of distinct objects.

The *Spot It* game requires the following properties to be true.

Property 1: $r \geq 2$

This must be true simply to make the game interesting. If there was only one object per card, the game would be trivial.

Property 2: $k \geq 2$

This must be true because each object must appear twice in order for cards to have an object in common.

There are several Lemmas for which will help prove a theorem that all *Spot It* games must follow.

Lemma 1: For any symmetric game, $Nr = kt$.

Proof: Since each of the t distinct objects appears k times, there are kt total objects. Every card has r objects and there are N cards, for a total of Nr objects. As a result, $Nr = kt$.
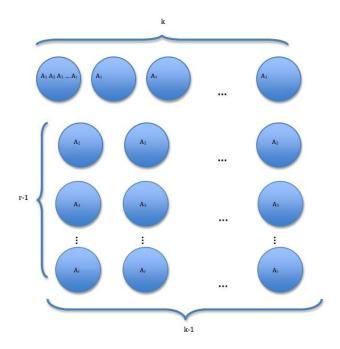
Lemma 2: For any complete game, $k(r - 1) = t - 1$.

Proof: If object A appears k times, each card on which A appears contains $r - 1$ distinct objects different from A. Thus, $k(r - 1)$ objects appear with A. Since each game is complete, every object appears with A. Thus $t - 1$ objects appear with A. Therefore, $k(r - 1) = (t - 1)$.

Lemma 3: In a symmetric game, $N = k + (r - 1)(k - 1)$.

Proof: Any card will have will have objects $A_1, A_2, \ldots, A_r$. The object A_1 will then appear on $k - 1$ more cards for a total of k, as shown in Figure 3 below.

The objects A_2 through A_r must then all appear $k - 1$ more times and these cards must all be different, because objects A_2 through A_r have already appeared together. This creates a total of $(r - 1)(k - 1)$ remaining cards (Figure 3). It is known that these are all the cards because if another card was added to the deck, it would have to have a matching object with every card, and there cannot be any more cards with objects A_2 through A_r.

Figure 10: This figure shows the appearance of certain objects in a *Spot It* game.

Adding these cards together results in $N = k + (r - 1)(k - 1)$.

Theorem 1: For a complete game, $r = k$ and $N = t = r^2 - r + 1$.

Proof: From the Lemmas it is known that $t = k(r - 1) + 1$ and $N = k + (r - 1)(k - 1)$. Substituting for t and N into $Nr = kt$, provides:

$$\left(k + (r - 1)(k - 1)\right)r = k(k(r - 1) + 1)$$

$$kr + r(r - 1)(k - 1) = k^2(r - 1) + k$$

$$kr - k + r(r - 1)(k - 1) - k^2(r - 1) = 0$$

$$k(r - 1) + r(r - 1)(k - 1) - k^2(r - 1) = 0$$

$$(r - 1)(k + r(k - 1) - k^2) = 0.$$

Since $r - 1 \neq 0$,

$$k + r(k - 1) - k^2 = 0$$

$$k - k^2 + rk - r = 0$$

$$k(1 - k) - r(1 - k) = 0$$

$$(1 - k)(k - r) = 0.$$

Since $k \neq 1$, we conclude that $k - r = 0$, and therefore $k = r$. This implies $N = t$. Finally, given $t = k(r - 1) + 1$, r can substitute for k to get $t = r(r - 1) + 1 = r^2 - r + 1$.

To develop a new version of *Spot It*, it is necessary to determine how many objects to include per card. For example, suppose we want to create a game with four objects per card, meaning $r = 4$. Using Theorem 1, it is known that $k = 4$ and that $N = t = 4^2 - 4 + 1 = 13$; therefore, the game will have thirteen cards with four objects per card. There will be thirteen distinct objects (which we will denote as 1, 2, 3, …, 13) and each object will appear four times, as shown in Table 1.

Table 4: This is a complete *Spot It* game with 13 cards and 4 objects per card.

1 2 3 4	1 5 6 7	1 8 9 10	1 11 12 13
2 5 8 11	2 6 9 12	2 7 10 13	
3 5 9 13	3 6 10 11	3 7 8 12	
4 5 10 12	4 6 8 13	4 7 9 11	

For another example, we created a game with $r = k = 5$; therefore, $N = t = 21$.

Table 5: This is a complete *Spot It* game with 21 cards and 5 objects per card.

1 2 3 4 5	1 6 7 8 9	1 10 11 12 13	1 14 15 16 17	1 18 19 20 21
2 6 10 14 18	3 6 11 17 20	4 6 12 15 21	5 6 13 16 19	
2 7 11 15 19	3 7 10 16 21	4 7 13 14 20	5 7 12 17 18	

2 8 12 16 20	3 8 13 15 18	4 8 10 17 19	5 8 11 14 21
2 9 13 17 21	3 9 12 14 19	4 9 11 16 18	5 9 10 15 20

The *Spot It* game is analogous to balanced incomplete block designs using each card as a block. By definition, a balanced incomplete block design is an arrangement of t distinct objects into N blocks such that each block contains exactly r distinct objects, each object occurs in exactly k different block, and every pair of distinct objects a_i, a_j occurs together in exactly λ blocks (Hall, 1986). The following is an example of a balanced incomplete block design with $r = k = 3$ and $N = t = 7$ and with $\lambda = 1$:

B_1: 0,1,3 B_2: 1,2,4 B_3: 2,3,5 B_4: 3,4,6 B_5: 4,5,0 B_6: 5,6,1 B_7: 6,0,2

A *Spot It* game is a balanced incomplete block design with $\lambda = 1$ along with the additional principle of only one matching symbol between two cards/blocks. However, a balanced incomplete block design is not necessarily a *Spot It* game. There are occurrences when a balanced incomplete block design has $\lambda = 1$ and still is not a *Spot It* game. For example, the following is a balanced incomplete block design with $N = 12$, $t = 9$, $r = 4$, $k = 3$, and $\lambda = 1$, but not a *Spot It* game.

B_1: 1,2,3 B_2: 4,5,6 B_3: 7,8,9 B_4: 1,4,7 B_5: 2,5,8 B_6: 3,6,9

B_7: 1,5,9 B_8: 2,6,7 B_9: 3,4,8 B_{10}: 1,6,8 B_{11}: 2,4,9 B_{12}: 3,5,7

Note that many of the blocks have nothing in common with another block, e.g. B_1, B_2, and B_3. Balanced incomplete block designs lack the singular matching symbol principle.

RESULTS AND DISCUSSION

The initial intent of this work was to develop an algorithm for creating a complete *Spot It* game of any size, and then develop a method for creating a template of the desired game. A user could simply choose the number of objects per card and then the game would be automatically created; however, while creating *Spot It* games of various sizes in an attempt to find a pattern, one cannot create a game with $r = 7$. It is found that a *Spot It* game cannot be created for all integers, in particular, $r = 7$.

Consider a smaller game, with the values $r = k = 3$ and $N = t = 7$:

ABC   ADE   AFG   BDF   BEG   CDG   CEF.

A matrix can be created with the rows corresponding to the symbols (letters) and the columns corresponding to the cards; specifically, let $a_{ij} = 1$ if object i appears on card$j$, and $a_{ij} = 0$ otherwise. This matrix is shown in Table 3.

Table 6: This matrix corresponds to a complete *Spot It* game with $r = 3$ and $N = 7$.

	#1	#2	#3	#4	#5	#6	#7
A	1	1	1	0	0	0	0
B	1	0	0	1	1	0	0
C	1	0	0	0	0	1	1
D	0	1	0	1	0	1	0
E	0	1	0	0	1	0	1
F	0	0	1	1	0	0	1
G	0	0	1	0	1	1	0

Note that the entries in each row and column of Table 3 will add up to three (since $r = k = 3$). Also, any two columns will have exactly one entry of 1 in the same row. This is from the only matching symbol property of *Spot It*. This matrix can be used to create linear functions $L_1, L_2, \dots, L_7$ of the variables $x_1, x_2, \dots, x_7$ (where x_i appears in L_j if and only if object i appears on card j):

$$L_1 = x_1 + x_2 + x_3$$

$$L_2 = x_1 + x_4 + x_5$$

$$L_3 = x_1 + x_6 + x_7$$

$$\vdots$$

$$L_7 = x_3 + x_5 + x_6.$$

Note that, squaring L_1 provides:

$$L_1{}^2 = (x_1 + x_2 + x_3)^2 = x_1{}^2 + x_2{}^2 + x_3{}^2 + 2x_1x_2 + 2x_1x_3 + 2x_2x_3.$$

Since each x_i appears exactly three times and also appears with every other variable exactly once, the following is derived:

$$L_1{}^2 + L_2{}^2 + \cdots + L_7{}^2 = (x_1 + x_2 + x_3)^2 + (x_1 + x_4 + x_5)^2 + \cdots + (x_3 + x_5 + x_6)^2$$
$$= 2(x_1{}^2 + x_2{}^2 + \cdots + x_7{}^2) + (x_1 + x_2 + \cdots + x_7)^2.$$

At this point, we would like to take advantage of Lagrange's Four Square Theorem to rewrite the factor $2(x_1{}^2 + x_2{}^2 + \cdots + x_7{}^2)$ as a sum of squares without the 2 in front. Specifically, we use identity 10.3.3 (Hall, 1986):

$$\left(b_1{}^2 + b_2{}^2 + b_3{}^2 + b_4{}^2\right)(x_1{}^2 + x_2{}^2 + x_3{}^2 + x_4{}^2) = y_1{}^2 + y_2{}^2 + y_3{}^2 + y_4{}^2$$

where

$$y_1 = b_1x_1 - b_2x_2 - b_3x_3 - b_4x_4$$

$$y_2 = b_2x_1 + b_1x_2 - b_4x_3 + b_3x_4$$

$$y_3 = b_3x_1 + b_4x_2 + b_1x_3 - b_2x_4$$

$$y_4 = b_4x_1 - b_3x_2 + b_2x_3 + b_1x_4.$$

To do this, however, an eighth term is needed. So, adding $2x_8{}^2$ to each side results in

Equation 1

$$L_1{}^2 + L_2{}^2 + \cdots + L_7{}^2 + 2x_8{}^2$$

$$= 2(x_1{}^2 + x_2{}^2 + \cdots + x_7{}^2 + x_8{}^2) + (x_1 + x_2 + \cdots + x_7)^2.$$

One can now write $2(x_1{}^2 + x_2{}^2 + \cdots + x_7{}^2 + x_8{}^2)$ as a sum of eight squares $y_1{}^2 + y_2{}^2 + \cdots + y_7{}^2 + y_8{}^2$ by defining:

$$y_1 = x_1 - x_2 \qquad y_2 = x_1 + x_2 \qquad y_3 = x_3 - x_4 \qquad y_4 = x_3 + x_4$$

$$y_5 = x_5 - x_6 \qquad y_6 = x_5 + x_6 \qquad y_7 = x_7 - x_8 \qquad y_8 = x_7 + x_8.$$

Therefore squaring and adding each of these together yields,

$$y_1{}^2 + y_2{}^2 + \cdots + y_7{}^2 + y_8{}^2 = 2(x_1{}^2 + x_2{}^2 + \cdots + x_7{}^2 + x_8{}^2).$$

Also, for simplicity, define $w = x_1 + x_2 + \cdots + x_7$. Thus, Equation 1 becomes

$$L_1{}^2 + L_2{}^2 + \cdots + L_7{}^2 + 2x_8{}^2 = y_1{}^2 + y_2{}^2 + \cdots + y_8{}^2 + w^2.$$

Note that

$$L_1 = x_1 + x_2 + x_3 = y_2 + \frac{1}{2}y_3 + \frac{1}{2}y_4.$$

Let

$$y_1 = y_2 + \frac{1}{2}y_3 + \frac{1}{2}y_4 = L_1.$$

Because $y_1 = L_1$ one can cancel to rewrite equation (1) as

$$L_2{}^2 + L_3{}^2 + \cdots + L_7{}^2 + 2x_8{}^2 = y_2{}^2 + y_3{}^2 + \cdots + y_8{}^2 + w^2.$$

Repeating this one can set $y_i = L_i$ (or $y_i = -L_i$) to get the following reductions:

$$L_3{}^2 + L_4{}^2 + \cdots + L_7{}^2 + 2x_8{}^2 = y_3{}^2 + y_4{}^2 + \cdots + y_8{}^2 + w^2$$

$$L_4{}^2 + \cdots + L_7{}^2 + 2x_8{}^2 = y_4{}^2 + \cdots + y_8{}^2 + w^2$$

$$\vdots$$

$$2x_8{}^2 = y_8{}^2 + w^2.$$

Because of these substitutions, it is known that x_8 and w are rational multiples of y_8 and therefore $2x_8{}^2 = y_8{}^2 + w^2$ has a nontrivial integer solution.

A similar argument can be made for any existing *Spot It* game. Now looking at the game structured with $r = 7$, it can be shown why it is impossible to create.

For $r = k = 7$ and $N = t = 43$, start in a similar way by defining $L_1, L_2, \ldots, L_{43}$ in terms of $x_1, x_2, \ldots, x_{43}$, where x_i appears in L_j if and only if object i appears on card j. For example, without loss of generality, we could have $L_1 = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$ (meaning the first card has objects one through seven). Then,

$$L_1^2 + L_2^2 \cdots L_{43}^2 = 6(x_1^2 + x_2^2 + \cdots + x_{43}^2) + (x_1 + x_2 + \cdots + x_{43})^2.$$

Since, each object appears seven times and also appears with every other variable exactly once. Adding $6x_{44}^2$ to each side yields

$$L_1^2 + L_2^2 \cdots L_{43}^2 + 6x_{44}^2 = 6(x_1^2 + x_2^2 + \cdots + x_{43}^2 + x_{44}^2) + (x_1 + x_2 + \cdots + x_{43})^2.$$

Using Hall's identity 10.3.3 again, another group of functions can be defined as $y_1, y_2, \ldots, y_{44}$ by

$$y_1 = 2x_1 - x_2 - x_3 \qquad y_2 = x_1 + 2x_2 + x_4$$

$$y_3 = x_1 + 2x_3 - x_4 \qquad y_4 = -x_2 + x_3 + 2x_4$$

$$\vdots$$

$$y_{41} = 2x_{41} - x_{42} - x_{43} \qquad y_{42} = x_{41} + 2x_{42} + x_{44}$$

$$y_{43} = x_{41} + 2x_{43} - x_{44} \qquad y_{44} = -x_{42} + x_{43} + 2x_{44}.$$

With an additional definition of $w = x_1 + x_2 + \cdots + x_{43}$, one obtains:

$$L_1^2 + L_2^2 + \cdots + L_{43}^2 + 6x_{44}^2 = y_1^2 + y_2^2 + \cdots + y_{43}^2 + y_{44}^2 + w^2.$$

After repeating the same process as above, so that $L_1^2 = y_1^2, L_2^2 = y_2^2, \cdots, L_{43}^2 = y_{43}^2$, the following equations results:

$$6x_{44}^2 = y_{44}^2 + w^2.$$

As before, it is known that x_{44} and w are rational multiples of y_{44}. So, after clearing out the denominators, it is observed that the equation $6x^2 = y^2 + w^2$ has a nontrivial integer solution (meaning not all variables are zero). However, this equation can't have a nontrivial integer solution because of the following argument by contradiction: first, if this equation has a nontrivial integer solution, then we can assume x, y, and w have no common factor greater than 1. If x, y, and w had a common divisor greater than 1, then one could factor this common divisor out from both sides of the equation and cancel it from both sides. Reducing the equation modulo 3, we have

$$y^2 + w^2 \equiv 0 (\text{mod } 3).$$

The possibilities for y are listed in Table 4 below.

Table 7: These are the only possible values for a square, modulo 3.

y	y^2 modulo 3
0	0
1	1
2	1

The same possibilities are true for w.

Because $y^2 + w^2 \equiv 0 (\text{mod } 3)$, we must have $y \equiv 0 (\text{mod } 3)$ and $w \equiv 0 (\text{mod } 3)$. Thus, $3|y$ and $3|w$. Consequently, $y = 3a$ and $w = 3b$ where a and b are integers, and the following can be written:

$$(3a)^2 + (3b)^2 = 6x^2$$

$$9a^2 + 9b^2 = 6x^2$$

$$3a^2 + 3b^2 = 2x^2$$

Therefore, $3|2x^2$. Since 3 and 2 are relatively prime, we can conclude that $3|x^2$ (Gallian, 2010). This implies, by Euclid's Lemma, that $3|x$. This is a contradiction because it is known

that x, y, and w have no common factor greater than 1. This contradiction means that no *Spot It* game is possible with these values.

When we began exploring the mathematics behind *Spot It,* we had hopes of developing an algorithm for creating various versions of the game. Mostly, the mathematics behind the game were more complicated than expected. There are still unanswered questions related to the Balanced Incomplete Block Design properties of the *Spot It* game.

ACKNOWLEDGEMENTS

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"Doing Gender" in Public Speaking Education: A Focus Group Analysis of Biological Sex and Gender Identity in Public Speaking Education

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ABSTRACT

This exploratory focus group analysis examines the ways in which students of a Capstone Communication Studies course ($N = 15$) perceive factors, such as their communication studies education, biological sex, and gender roles, that have impacted their experiences with Public Speaking Anxiety (PSA) and Self-Perceived Communication Competence (SPCC), as well as the effectiveness of various treatment methods for the reduction of PSA. Three independent student focus groups were conducted – one comprised of biological females ($n = 5$), one of males ($n = 3$), and one containing subjects of both biological sexes ($n = 7$). Herein participants discussed their personal experiences with PSA, and whether/how their education within the communications major aided them in overcoming it. Results were analyzed using thematic analysis to draw implications for the enhancement of instructional PSA mitigation methodologies and to determine whether different PSA treatments are more effective for one biological sex or the other, or based upon identified gender roles.

INTRODUCTION

In the United States, between 30 and 40 percent of individuals suffer from PSA – the most common manifestation of communication apprehension – to an extent that inhibits their abilities to succeed in personal and professional realms alike (McCourt, 2007; McCroskey,

1984). As early as 1965, researchers have sought to identify and understand the various presentations of anxiety related to oral communication and communication situations (Glaser, 1981). As awareness of the prevalence and potential impediments associated with maladies of this type continues to expand and evolve, likewise do efforts to discover their most effective remedies. Glaser (1981) was one of the first to suggest that the complex and multidimensional nature of communication apprehension warranted an equally multifaceted educational approach to its reduction. He proposed three primary models "to explain the etiology, maintenance, and treatment" of communication apprehension: conditioned anxiety, negative cognitive appraisal, and skills deficit (Glaser, 1981, p. 322). Considerable research focused on determining the effectiveness of various educational treatments has drawn upon this model and, in coordination with its trilateral nature, three methods of approach are commonly assessed in order to address each of these elements: exposure therapy, cognitive modification, and competence training (Ady, 1987; Finn, Sawyer, & Schrodt; Hunter, Westwick, & Haleta, 2014; McCourt, 2007). Multiple studies have sought to evaluate the effectiveness of programs that utilize an integrative approach to the reduction of PSA. Of these studies, those focused on the variable of biological sex in their methodological assessments reveal that biological females consistently experience higher levels of PSA than do males (Hunter, et al., 2014). In a recent study conducted at a Midwestern university, a pre-test post-test analysis revealed that, while students of both biological sexes achieved significant reduction in PSA following completion of the basic public speaking course, female students exhibited a significantly greater response to treatments, substantially reducing the disparity between the sexes (Hunter, et al., 2014). These results indicate the need for a closer examination of the role of socially-constructed gender identity, in addition to biological sex, as an indicator of both susceptibility to PSA and receptiveness to educational treatment methods.

In the realm of academia, much controversy surrounds the distinction between gender and biological sex, as evidenced by the wealth of research existing on the subject. This distinction represents a shift from previous, essentialist ascriptions of male and female traits to the consideration of gender as a socially-constructed practice, independent of biological sex (Bem, 1981; Tortajada & Van Bauwel, 2012; van den Brink & Stobbe, 2009). West and Zimmerman's (1987) seminal article introducing the concept of "doing gender" was an elemental contribution to this shift; their definition of gender is sociological in nature,

reliant upon codes and customs that are foundational in everyday activities (van den Brink & Stobbe, 2009; West & Zimmerman, 1987). "Doing gender" refers to the complex and continuous process of societal interactions, perceptions, and activities that characterize individual endeavors as expressions of either masculine or feminine qualities (Sullivan & Kedrowicz, 2011; van den Brink & Stobbe, 2009).

In an effort to understand this distinction in the context of public speaking education, this study focuses on the perceptions of student participants and their experiences with PSA within the communications major. In addition to PSA and Communication Competence (CC), this study examines communication biases related to biological sex and gender identity and elaborates on the integrative approach to PSA reduction and the potential relationships between biological sex, socialized gender, and the effectiveness of these treatment methods. In short, how is communication education "doing gender."

Biological Sex, Public Speaking Anxiety, and Communication Competence

The pervasiveness and potential liabilities of PSA within educational systems has been the subject of copious quantities of research over the years. Historically, a variety of labels have been allocated to the many different manifestations of communication related anxiety: stage fright, social anxiety, communication apprehension, and performance anxiety (Bodie, 2010; Glaser, 1981). It is, however, important to note that, as Glaser (1981) attests, "This variation in terminology is more than semantic; the differences represent disparate orientations toward explaining a complex communication problem" (p. 321). Therefore, for the purposes of this study, PSA is defined as "a specific, communication-based anxiety in which individuals experience physiological arousal, negative cognitions, or behavioral responses to real or anticipated presentations" (Dwyer & Davidson, 2012, p. 100). This type of anxiety afflicts nearly 40 percent of Americans, and its symptoms, ranging from minor increases in heart rate and sweating to confusion, dizziness, and the complete inability to speak, can greatly inhibit an individual's ability to succeed in personal, professional, and educational pursuits alike when experienced in high levels (McCroskey, 1984).

The development of communication competence, however, or "…the quality of interaction behavior in various contexts," (Canary & Spitzberg, 1987, p. 43) is evidenced to be an

effective means of reducing PSA (Ellis, 1995; Rubin, Welch, & Buerkel, 1995). Furthermore, in a study conducted to examine the relationships between public speaking anxiety, self-perceived public speaking competency, and teacher immediacy, researcher Ellis (1995) asserted the following: "Indeed, research indicates that perceptions of communicative ability may be central to apprehension" (p. 65). Additionally, as Osorio, Crippa, and Loureiro (2008) asserted, "The extent to which this condition is experienced has an inhibitory or facilitating influence on the development of communication competence and communication skill"

Research also suggests that women (biological females) are somewhat disadvantaged in this capacity, as they commonly report higher levels of PSA and communication anxiety in general (Behnke & Sawyer, 2000; Hunter, et al., 2014 & McCroskey, 1984). Moreover, as Bem (1981) asserted, within contemporary American culture, societal rewards are afforded to those whose behavior conforms to social expectations of normality as they apply to one's biological sex. Essentially, a woman receives societal rewards for feminine behavior, as do men who are perceived as masculine.

Blended Approach to PSA Reduction

As previously mentioned, many institutions have implemented a multifaceted design into their basic public speaking courses in an effort to address issues related to PSA and the development of communication competency. A recent study examines the effectiveness of a three-pronged approach to PSA mitigation that has been commended as "more effective than any single method" (Hunter, et al., 2013; Pribyl et al, 2001, p.149). The three instructional methods employed are exposure therapy, cognitive modification, and skills (or competence) training. Exposure therapy involves repeated exposure to gradually more and more complex or challenging speaking scenarios in an effort to treat the psychological arousal associated with PSA through desensitization (Bodie, 2010; Hunter, et al., 2013). Fremouw and Scott (1979) elaborate on the second process – cognitive modification - in their study, which involved training students to recognize and reflect upon negative attitudes and self-statements in regards to speaking situations, and displacing those attitudes with more productive coping strategies and strength-based feedback. Finally, skills training can increase a student's level of self-perceived communication competence, thereby reducing PSA.

Although previous findings indicated that women tend to experience higher levels of PSA than men have been criticized as essentialist, recent research has supported these findings quantitatively and has furthermore confirmed that public speaking education can be successful in the mitigation of PSA for men and women, alike. For those individuals who experience high levels of PSA, and are therefore prone to its negative and inhibiting effects on their personal satisfaction and accomplishment of professional goals, refining the treatment techniques employed within these courses is imperative. To this end, I propose the following research questions:

RQ1: How does biological sex impact students' perceptions of their own public speaking experiences?

RQ2: How does gender impact students' perceptions of their own public speaking experiences?

METHODS

Participants

Participants in this study were junior and senior speech communication majors at a mid-sized Midwestern university. Each of these students were currently enrolled in the Capstone Communications course, and all had completed and received assessments and feedback from multiple communication courses including at least one in public speaking. The students were divided into three individual focus groups according to their biological sex; one group was entirely composed of females ($n = 5$), one of males ($n = 3$), and the third was a combination of the two ($n = 7$).

Procedure

Upon receiving approval through university human subjects review, students were informed via email of the opportunity to participate in this study, wherein it was stated that they would be awarded five points of extra credit for taking part in an online survey and participating in one of three focus group sessions. Students were informed that these points would only be awarded to those who completed both aspects of this study. The email also included a link to the QuestionPro© survey site, which included a brief demographics questionnaire (age, ethnicity, biological sex, and major/ minor studies) and a letter of informed consent stating that completion of the survey to participate in the study.

With the instructor's permission, the focus group sessions were conducted within the usual

class time-frame, facilitated by the researcher in the absence of the instructor, to decrease the potential for researcher-introduced bias. At the beginning of each session, students were offered the opportunity to review the letter of informed consent, and were reminded that their participation was strictly voluntary. Additionally, subjects were informed that the sessions would be recorded, and were asked to verbally consent to this when the recordings began. Finally, students were assured that every effort would be taken to ensure the anonymity of their remarks; all transcriptions of the sessions would be done by the researcher alone, all transcriptions would be anonymized by leaving out potentially-identifying information from the transcripts, and the recordings would be destroyed following transcription.

Thematic Analysis

The primary aim of thematic analysis is to identify themes within a text or conversation. In this case, the themes were identified within the focus group recordings and transcriptions according to the three criteria of thematic analysis, as established by Owen (1984). These criteria are recurrence, repetition, and forcefulness. Throughout the process of analysis, themes which recurred with regularity were noted and logged, as were those themes which were often repeated during students' responses to facilitator inquiries. Additionally, forcefulness was assessed by examining "vocal inflection, volume, or dramatic pauses which serve to stress and subordinate some utterances from other locutions," all of which were recorded in the transcriptions (p. 275).

RESULTS AND DISCUSSION

In the thematic analysis of student focus group transcripts, four primary themes emerged: 1) Students, both male and female, reported feeling very low levels of PSA, 2) they believed that socialized gender was a more important predictor of PSA and SPCC than biological sex, 3) they stated that, perhaps, the communication major taught women to speak using more stereotypically masculine tendencies, especially within public speaking situations, perhaps explaining their felt lack of PSA, 4) students, male and female, alike, were hesitant to agree that socialized gender roles aligned along traditionally-viewed lines, and yet, their communication continued to affirm the existence of those roles and 5) participants discussed concerns that gender bias regarding expected communication behavior, in some cases, may more strongly and negatively impact males than females.

First, participants reported that they felt very little apprehension and a great deal of confidence and competence in public speaking and other communication situations. Some reported being attracted to the communication major as a result of having already felt strong self-assurance in their communication. Others stated that the major was elemental in alleviating their apprehension. All agreed that the major had played a major role in helping them develop their current levels of communication competence and confidence.

Secondly, they expressed belief that, while biological sex may influence PSA and SPCC, socialized personality traits are far more significant indicators. They stated that, although the women in the Capstone Course did not feel PSA to a large extent – possibly due to the fact that they did not necessarily identify with the stereotypical depictions of men as masculine and women as feminine – they believed this to be a result not of their sex (or gender), but of their individual background and experience. They cited their collegiate experience as a place where gender roles often blended and even, at times, seemed to reverse.

The concept did emerge, however, that individuals who demonstrate certain personality traits typically regarded as "masculine" are often considered more confident and capable in public speaking situations. The women interviewed in the focus group identified strongly with these communication characteristics. Focus group participants expressed noticeable improvement in PSA and SPCC throughout the development of their studies in this field, even asserting that the major taught them to "talk like a man." Interestingly, within the themes that emerged from the thematic analysis, some contradictory beliefs were evident, particularly in the case of the female participants. Although apparent was the recurrence, repetition, and forcefulness of the belief that women are not, biologically speaking, more prone to suffering from PSA, female students also asserted that they were more likely to demonstrate "masculine" qualities when actively delivering a speech in an academic setting than in other settings.

Some reticence, and even some distinguishable uneasiness, was noted when students (females) were asked if they believed that their biological sex or gender related traits had any impact (either positive or negative) on their experiences with PSA or their level of competence. For example, one student, at varying points in the session, made the following remarks: "I hate calling them [character traits] masculine;" "I like to be, like, to speak my mind, or because I can fly off the handle or just be, like, ridiculous – I don't feel like that's

a strictly masculine trait;" "historically speaking, women weren't allowed to be like that;" and "…I feel like almost all the females I know in the communication major have more masculine traits. Where, we're all, like, less afraid to speak our minds." This student made it clear that the labels of masculinity and femininity were distasteful to her, yet at other times, she confirmed and validated their existence.

Finally, student responses thematically validated their beliefs that gender biases do, indeed, exist especially with regard to perceived violations of expected gender behavior by males. One student recalled an occasion on which, while watching a documentary, she afforded credibility to the speaker – who had a high-pitched, "feminine" voice – until she saw his face. At this point, she was unable to take him seriously, owing to the fact that the narrator exhibited qualities that contradicted expectations of how masculinity should be performed or represented. Another student confirmed her feelings; "…guys with like, high-pitched voices are like, people literally, uh, don't take them as seriously. …they kind of, like, make fun of them in the crowd." This assertion is consistent with Bem's work, which posits that men and women are rewarded in society by behaving in ways that conform to the socially-constructed framework consistent with their biological sex (Bem, 1974).

Implications and Future Research

In general, the fields of studies known as the "soft sciences" are populated with a higher ratio of women to men. In the field of communications alone, an American Community Survey Report found that over 60 percent of the bachelor's degrees awarded in 2009 were earned by women (Siebens & Ryan, 2012). Although the sample for this study was small, the numbers represent a larger trend. The emergent themes within the focus group texts present some interesting notions regarding socialized gender, specifically within the field of communication studies. While the findings of this study cannot afford an answer to whether or not specific gender-related characteristics make one more or less susceptible to PSA or receptive to treatments, it does suggest that further inquiry into the emergent themes may provide a great deal more insight into the topic.

The primary question that arises is one regarding the emergent theme that the educational system teaches women to "talk like a man," or that the communication discipline or the department in question, in particular, has a particular draw for women who already possess certain characteristics associated with masculinity. Which of these is actually the case? In

order to address this question, I suggest a longitudinal study employing both quantitative and qualitative measures. In addition to participation in focus groups, students within the communication major would be required to complete a pre-test and post-test at the beginning and end of each academic year, respectively. The suggested instrumentation for these studies includes three scales: the Personal Report of Public Speaking Anxiety (PRPSA) (McCroskey, 1970), the Self-Perceived Communication Competence (SPCC) scale (McCroskey & McCroskey, 1988), and Bem's (1981) Sex-Role Inventory (BSRI), which assesses masculine, feminine, and androgynous character traits. By following students from the start of their educational career in communication, patterns may emerge that provide evidence as to whether it is the system or the subjects that result in a higher ratio of female students with stereotypically masculine speech characteristics.

LIMITATIONS

Consisting of only fifteen participants, this study was limited primarily in regards to its sample. Fifteen is too small to allow for any findings to be generalizable to a larger population. This limitation was, however, unavoidable, as the aim of this study was to investigate the experiences of students nearing the completion of their communication studies degree. A second limitation is also related to the sampling frame and procedures. The participants represented a homogenous demographic, and therefore, were not representative of students in other areas of the country, or participating in other types of communication programs. Furthermore, these demographics represented an extremely limited racial and ethnic variation. Students of varying cultural backgrounds may experience public speaking education quite differently, and may have extraordinarily different experiences with PSA and communication competence.

Future Directions

As suggested earlier, in light of the findings of this study, future research should compare quantitative pre- and post-test findings about PSA and SPCC as well as socialized gender to the qualitative findings of this study. Additionally, performing research with a larger sample including students of varied ethnic backgrounds and from multiple institutions will enhance the potential for generalizability of the study's findings.

CONCLUSION

Rarely, after decades of research on the persistent affliction of public speaking anxiety, has the subject been approached through a qualitative lens. The addition of the factors of biological sex and its relationship to socialized gender may provide valuable insight into the refinement of educational PSA treatment methods. This exploratory focus group analysis examined students' perspectives on the impact of biological sex and socialized gender identity on their personal experiences with PSA and competency within their communication education. Primarily, thematic analysis revealed that students perceived socialized character traits to be a far greater indicator of PSA susceptibility and communicative capability. Contradictory statements by focus group participants, however, leave researchers with many questions to be addressed in the future – not the least of which is this: does communication education teach its students to "talk like a man?"

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Vibrations Analysis on Tennis Racket String

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ABSTRACT

The purpose of this project was to investigate and analyse the vibration of a tennis racket string when a ball is hit. This was done using concepts of mechanical vibrations and modelled using Microsoft Excel. The displacement of the tennis string over time was graphed for two different positions on the racket and two different relative speeds of the tennis ball. It was found that the position of the tennis ball on the racket has very little effect on the displacement of the strings. If the ball or racket is moving faster when the ball is hit, then the displacement of the strings is proportionally greater. There were a few factors in the modelling that were unlike the actual vibration of a tennis string. This model did not take in to account the fact that the tennis ball would deform when it is hit or the deflection of the tennis racket. The designed model will help compare different spring constants and ball speeds for different scenarios.

INTRODUCTION

Tennis is a sport enjoyed around the globe by participants of varying ages and abilities. It is important for a tennis racket to be well designed to maximize performance and minimize injury. There are many different aspects of a tennis racket that can affect how the tennis ball comes off the strings. One of the main factors to take into account is the vibration that occurs when the ball is hit. If there is too much vibration in the racket or the strings, this vibration can be carried down the racket handle to the player's arm and cause wear or injury such as tennis elbow.

This study looks into the vibration of a tennis racket string during and after the ball is struck. Due to the large number of variables relating to the mechanisms of string vibration,

a simplified model was created in order to perform vibrational analysis. This model is shown in Figure 11. It assumes that rather than the racket frame and the tennis ball both moving with a certain velocity in opposite directions. The racket is fixed and the ball is moving at its speed plus the speed the racket is moving when it is hit. This is effectively the relative velocity of the ball in relation to the tennis strings. In the diagram, the spring and dampener are shown as fixed, this is to help visualize what is happening when the ball hits and the string starts vibrating. The mass of the tennis ball is involved in the diagram.
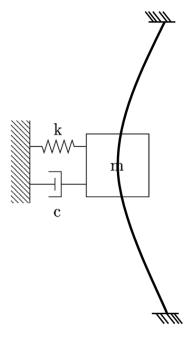

Figure 11: This is a simplified model of the tennis string vibrations.

METHODS

Spring Constant Calculation

To calculate the spring constant for the tennis racket, a re-stringer and a 4.5 kg weight were used. The re-stringer was strung with one string going into and out of the racket creating two lines of string. It was strung at tensions of 26 kg and 28 kg and the initial distance

from the top of the frame to the string was measured and tabulated. The 4.5 kg weight was hung from the string and the final displacement was measured and tabulated. The spring constant was found using Hooke's Law as follows:

$$F = kx \tag{1}$$

By dividing the force of 4.5 kg by the displacement of the string, the spring constant can be calculated. This was done a total of six times, one for each of the three string set-ups and each of the two tensions. The three different string set-ups were as follows:

Figure 12: These are the three different string positions on a tennis racket.

To find the value of the equivalent spring constant when the ball hits the racket, the assumption was made that the ball will hit four strings in the vertical direction and four strings in the horizontal direction. These strings will be the only strings that affected the spring constant. They were effectively connected in parallel; therefore, the spring constants were added together as follows:

$$K_{eq} = 2K_a + 2K_b \tag{2}$$

K_a and K_b are the average spring constant values at a given position.

For the analysis, two positions on the racket were investigated and compared. The two positions are shown in Figure 13.
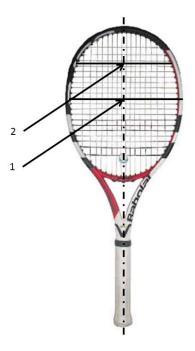

Figure 13: Position 1 and Position 2 on the tennis racket were investigated and compared.

The spring constant used for position one was calculated using the values obtained for set-up 1 and 3 spring constants. This calculation is given below.

$$K_{eq} = 2K_1 + 2K_3 \tag{3}$$

$$K_{eq} = 2 \times 3{,}241 + 2 \times 4{,}684$$

$$K_{eq} = 15851 N/m$$

The spring constant for the second position was found in the same way, calculating to be 15,907 N/m.

A set up of the re-stringer is shown Figure 14. There is a weight tied to the strings and the deflection of the strings was measured. This picture shows the strings at position 1 as per Figure 12.
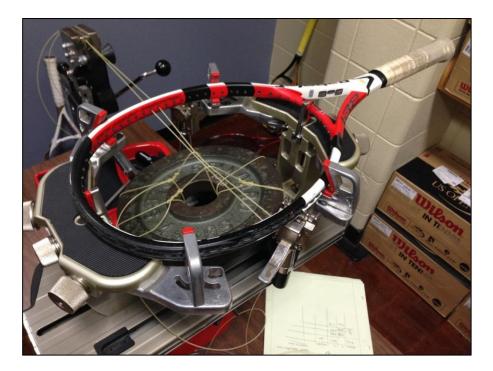

Figure 14: The setup of a re-stringer in order to calculate the spring constant.

Assumptions and simplified system

There are a vast number of factors involved in the vibration of a tennis string. In order to derive an equation of motion, a simplified system is needed to be made and assumptions are needed to be defined. Even though the simplified models created were not exactly the

same as the actual vibration of a fully strung tennis racket being used in a tennis match, they were similar enough to compare different scenarios. Some of the factors that could affect the vibration of a tennis racket string include:

    i.   Location where tennis ball is hit on the racket.

    ii.   Amount of mains and crosses on the tennis racket (the number of vertical and horizontal strings the racket has).

    iii.   The tension of the tennis strings.

    iv.   The speed of the ball and the speed of the racket when contact is made.

    v.   The time the ball is in contact with the tennis racket.

    vi.   The shape of the racket frame.

    vii.   The type of string used in the racket (some strings are more flexible or thinner than others).

    viii. The type of tennis ball being hit (tennis balls are pressurized and will deform differently).

This is only a basic list of factors that affect the vibration of the tennis strings. It is noted that there may be many more not identified.

Furthermore, assumptions are made based on the level of analysis and the factors measured using basic equipment. The simplified system that we have created using a single string will have an amplified vibration rather than a fully strung racket with strings crossing over each other going horizontally and. This is because of the spring constant, k, of the single string being vastly smaller than an entire system. It would be difficult to measure the spring constant of the strings on a fully strung racket, because the force needed to be applied on the strings would be huge and the deflection would be small creating a large amount of error. Other assumptions that have been made in order to create an equation of motion are as follows:

    1.   Neglect mass of the strings and deformation of the tennis ball.

            This can be done because the mass of the tennis strings is very small. This project looks at comparing different scenarios related to the length of tennis string and the tension which allows for the deformation of the tennis ball to

be neglected. Neglecting this deformation will mean that the modelled displacement of the tennis strings will be larger than the actual deformation.

2. The tennis ball (applied force) is hit in the exact middle (horizontally) of the racket.

   To simplify the equation of motion, it is necessary to make this assumption. Otherwise the equations created will be different for each point that the tennis ball is hitting. This assumption is valid because professional tennis players and college tennis players hit the middle of the strings a large percentage of the time in order to maximize power and accuracy.

3. The mass of the system is the mass of the tennis ball and it is constant the entire time the strings are moving.

   Since the tennis ball is in contact with the strings for a majority of the time the strings are vibrating and the vibration of the strings is tiny, this approximation can be used for the basic model.

4. The tennis ball is traveling perpendicular to the racket strings and parallel to the deformation of the tennis strings.

   Often when a tennis ball is hit, it does not come perpendicular to the strings, but this assumption is necessary to simplify the equation of motion and find the relative velocity of the tennis ball to the racket.

5. The spring constant of the strings is constant.

   Due to the fact that as the ball hits the strings and they deform (lengthen), the tension in the strings slightly increases. This means that the string deformation would be non-linear. It is necessary to assume that this is not the case, so that we can use the equations of motion we have learned in class.

RESULTS

Free Body Diagram

A free body diagram of the vibration system was created in order to form an equation of motion. The diagram is shown below in Figure 15.
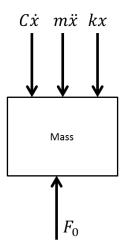

Figure 15: This figure is a free body diagram of vibrations system.

Where: $C\dot{x} = Damping\ Force$

$m\ddot{x} = Inertial\ Force$

$kx = Spring\ Force$

$F_0 = Force\ of\ the\ tennis\ ball$

Equation of Motion

The equation of motion for the system can be obtained by writing a force balance for the free body diagram in Figure 15. When the forces in the x-direction are balanced, we get the following equation:

$$m\ddot{x} + c\dot{x} + kx = F_0 \tag{4}$$

The convolution of integral was used to solve this equation where F_0 was applied for a small period of time and $F(\tau)$ is shown in Figure 16 (not to scale). $F(\tau)$ represents the force of the tennis ball over time.
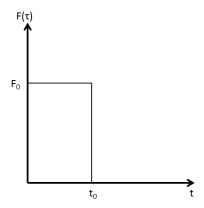

Figure 16: This graph compares force vs time graph for convolution of integral.

The basic form for the convolution of integral equation was used to start with and is given below.

$$X(t) = \frac{1}{m\omega_d} \int_0^t F(\tau)e^{-\zeta\omega_n(t-\tau)}\sin\omega_d(t-\tau)d\tau \tag{5}$$

The force function shown in Figure 16 can be rewritten as follows:

$$F(t) = \begin{cases} F_0, & 0 < t < t_0 \\ 0, & t \geq t_0 \end{cases} \tag{6}$$

Where: $F_0 = Maximum\ force\ of\ the\ tennis\ ball$

$t_0 = Time\ the\ tennis\ ball\ is\ in\ contact\ with\ the\ strings$

Substituting this into the convolution of integral equation and solving for the time interval $0 < t < t_o$ gives the following:

$$x(t) = \frac{F_o}{m\omega_d} \int_0^t e^{-\zeta\omega_n(t-\tau)} \sin\omega_d(t-\tau)d\tau$$

(7)

$$x(t) = \frac{F_o}{m\omega_d} \frac{1}{(\zeta\omega_n)^2 + \omega_d^2} \left[\left[e^{-\zeta\omega_n(t-\tau)}\right] + \left[\zeta\omega_n\sin\omega_d(t-\tau) + \omega_d\cos\omega_d(t-\tau)\right]\right]\Big|_0^t$$

$$x(t) = \frac{F_o}{m\omega_d[(\zeta\omega_n)^2+\omega_d^2]} \left[\omega_d - e^{-\zeta\omega_n t}[\zeta\omega_n\sin\omega_d(t) + \omega_d\cos\omega_d(t)]\right]$$

(8)

Evaluating the integral from 0 to t_0 for the interval of $t > t_0$ gives the following equation:

$$x(t) = \frac{F_o}{m\omega_d[(\zeta\omega_n)^2+\omega_d^2]} \left[e^{-\zeta\omega_n(t-t_0)}[\zeta\omega_n\sin\omega_d(t-t_0) + \omega_d\cos\omega_d(t-t_0)] - \right.$$
$$\left. e^{-\zeta\omega_n t}[\zeta\omega_n\sin\omega_d(t) + \omega_d\cos\omega_d(t)]\right]$$

(9)

Where: $x(t) = Displacement\ of\ the\ tennis\ racket\ strings\ over\ time$

$m = mass\ of\ the\ system$

$\zeta = Damping\ ratio$

$\omega_n = Natural\ frequency\ of\ vibration$

$\omega_d = Damping\ frequency\ of\ vibration$

Graphical Analysis

For the graphical analysis, values need to be calculated and input into the equations above.

To find F_0, first the velocity and mass of a tennis ball needed to be known. The official mass of a tennis ball is 56.7 g. For the velocity, the relative velocity needed to be used as the system is modelled as a stationary racket. To take an extreme case, the racket head speed of Roger Federer's racket and the speed of a forehand hit by professional tennis players were used. The rotational speed of Federer's racket when he is hitting a forehand is about 2400 rpm. A slower forehand would be around 700 rpm. If a lever arm value of 0.63 m is used, which includes the length to the center of the racket as well as 10 cm from the wrist up the forearm to the center of rotation, then the approximate speed of the racket at the point where the ball is hit can be obtained by the following equations:

$$\omega = \frac{2400rev}{min}(2\pi\frac{rad}{rev})(\frac{1min}{60sec})$$

$$\omega = \frac{251rad}{sec}$$

$$V_r = \omega r$$

$$V_r = \frac{251}{s}(0.63m)$$

$$V_r = 158\frac{m}{s}$$

for a racket head speed of 2400rpm, and

$$V_r = 46.2\frac{m}{s}$$

for a speed of 700rpm.

The speed of the tennis ball used is 120.7 km/hr (75 mph) which would be the speed of a powerful forehand [2]. This can be converted into $V_b = 33.5$ m/s. Adding V_b and V_r together to obtain the relative velocity of the tennis ball on the strings gives:

$$V_{rel} = 191.5\frac{m}{s}$$

for a speed of 2400 rpm, and

$$V_{rel} = 79.7\frac{m}{s}$$

for a speed of 700 rpm.

From the R.Cross essay [1] the contact time the ball is on the racket is 4 m/s. If this value is used, then the average acceleration and force for a speed of 2400 rpm can be found as follows:

$$a = \frac{v}{t}$$

$$a = \frac{191.5}{0.004}$$

$$a = 47875 \frac{m}{s^2}$$

$$F = ma$$

$$F = 0.0567 \times 47875$$

$$F = 2715N$$

For a speed of 700 rpm, the acceleration and force are:

$$a = 19925 \frac{m}{s^2}$$

$$F = 1130N$$

The natural frequency and the damped frequency can be calculated as shown:

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$\omega_d = \omega_n\sqrt{1 - \zeta^2}$$

For the values of ζ, a value of 0.03 was assumed as this made the vibration system look most realistic.

Figure 17 through Figure 19 show the displacement of the tennis strings given certain conditions. Figure 17 and Figure 18 show the displacement of the strings at the different positions of the racket given the different spring constants at the slower speed and Figure 19 shows the displacement at the larger speed of 2400 rpm.
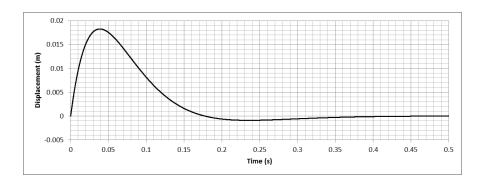
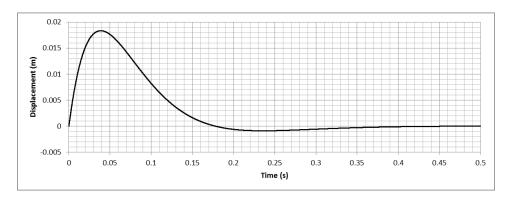**Figure 17:** The displacement of strings at position one.

Figure 18: The displacement of strings at position two is displayed in this figure.
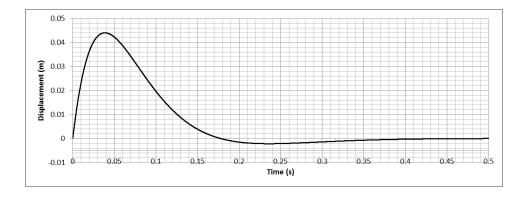

Figure 19: The displacement of strings with a force of at 2400 rpm.

CONCLUSION

The purpose of this project was to measure the movement of tennis racket strings after they have been struck by a tennis ball. This was performed by doing a thorough analysis and finding an equation of motion for the strings. The spring constant value needed for the equation of motion was found using a racket re-stringer and applying a known amount of weight to different string tensions. The equation of motion was found by writing a force balance of the free body diagram of the vibration system. The string position was then solved for using the convolution of integral method. The equation of motion obtained was then graphed, and can be seen Figure 17 through Figure 19. Figure 17 and Figure 18 do not vary much as the variation of the spring constant was so small. This means that there will only be a slight decrease in string vibration when the position the ball is hit changes.

Figure 19 is an extreme example at a high speed; therefore, the results may be skewed. At such a high speed, the tennis ball deforms a greater amount, more than the strings. The deformation of the ball was not taken into account during this project, which would be the cause for some error in the results of the movement of the strings. It is unrealistic that the strings deform a whole 4 cm, so the deformation of the ball must be taken into account. This deformation would have meant that the force applied to the strings would have been less because the speed of the ball was effectively 'cushioned' by the ball deformation. This would have been the case in the other examples at a lower speed as well but not to such a large extent. The higher applied force on the tennis strings may even change the spring constant because the strings would lengthen as the force is applied.

The comparison of the two different speeds show, as expected, that the deformation of the strings is a lot higher with the higher relative speed of the tennis ball. For the slower speed, the maximum deformation read from the graph is about 1.85 cm. The faster speed had a maximum deformation of 4.4 cm. The difference in force between these two scenarios was 1130 N and 2715 N for the slower and faster speeds respectively. This was a 140% increase in force applied and it yielded a 138% greater maximum displacement. This shows that the increase in force is directly proportional to the increase in maximum displacement provided all other constants remain the same. This is expected from looking at the equation of motion.

REFERENCES

[1] Cross, R. Flexible beam analysis of the effects of string tension and frame stiffness on racket performance. (2000) *Sports Engineering*, 3, 111-122.

[2] SpeedMaster (2011) Forehand Speed and Spin Rates of the ATP Stars, from http://blog.tennisspeed.com/2011/01/forehand-speed-and-spin-rates-of-atp.html