INCONSISTENCY IN THE LINE SPREAD TEST AS AN OBJECTIVE MEASUREMENT OF THICKENED LIQUIDS

A Thesis by

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I have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Arts with a major in Communication Sciences and Disorders.

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DEDICATION

To my father who values education and supported my graduate study with his love, my mother who is guiding me from Heaven, and my brother, T.R., a good friend.

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ABSTRACT

There is no objective measurement clinically used to confirm consistency of thickened liquids in dysphagia management. This research was designed to examine the line spread test (LST) as an objective measurement following Paik et al.'s (2004) LST tool model with its acceptable ranges of thickened liquids. The original method was to measure nectar and honey consistency of thickened liquids mixed by four naïve adults, four SLPs, four dietary staff members, four licensed nurses, and four registered nurses. In the initial three naïve adult's trials: 10 out of 12 cases for nectar consistency failed to meet the acceptable range and 1 out of 12 cases for honey consistency failed. From this preliminary data, the clinical validity of the LST tool was questioned. The research method was modified to measure LST values of pure drinks. The LST measure was performed by the investigator, four SLPs, and six naïve adults. The objectives of this modified research were to obtain LST values of pure base drink and to verify what caused the discrepancy in LST values. It was found that using different plates (glass and Plexiglas) caused significant differences in LST value of all pure base drinks. Overall values measured on a Plexiglas plate were less than those on a glass plate. No significant difference was found for person who performed the LST or time of day the LST was performed.

This research found that the LST tool was not a reliable method to measure the consistency of thickened liquids. Depending on which plate was used, LST values obtained varied for all base drinks. Measurements obtained in this study did not agree with values reported by Paik et al. (2004).

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LIST OF ABBREVIATIONS

EMG	Electromyography
LST	Line Spread Test
OOI	Orbicularis Oris Inferior Region
SA	Swallowing Apnea
SLP	Speech-Language Pathologist
VFSS	Videofluoroscopic Swallow Study

CHAPTER 1

INTRODUCTION

Dysphagia refers to difficulty in moving food from the mouth to the stomach due to an abnormality in behavioral, sensory, and preliminary motor acts in preparation for the swallow and during the swallow. Dysphagia is also triggered when the functions of cognitive awareness of the eating situation, visual recognition of food, and all of the physiologic responses to the smell and presence of food (such as increased salivation) are deficient (Logemann, 1998). Dysphagia is a common symptom of underlying disease or a result of a variety of congenital abnormalities, structural damage, and/or medical conditions across all age groups (Groher, 1997; Logemann, 1998). According to the U.S. Census Bureau (2000), an estimated 16,500,000 individuals will require care for dysphagia by the year 2010.

The purpose of dysphagia management with patients who can feed orally is to achieve safe swallowing while pursuing adequate nutrition and hydration. Safe swallowing means that there is no residue in the oral cavity and from the pharynx to the esophagus and no aspiration. Aspiration is the leading symptom of impaired-airway protection during swallowing in patients with dysphagia. It is the most serious complication of dysphagia because it can result in persistent cough, recurrent pyrexia (abnormal elevation of body temperature), reversible airway disease, recurrent pneumonia, chest pain, lung disease, confusion, and convulsions due to asphyxiation (presence of noxious agents), malnutrition, and dehydration (Penman & Thomson, 1998). Aspiration of small amounts of gastric or oral secretion occurs in up to 45 percent of the healthy population and is not thought to be harmful. However, aspiration in patients with dysphagia is always assumed to be significantly dangerous (Cass, Willis, Ryan, Reilly, & McHugh, 2005), even to the point of threatening mortality, especially in patients with stroke (Rosenvinge & Starke, 2005).

To prevent aspiration and improve swallowing, different compensatory strategies are performed, depending on the conditions of the patients. Compensatory strategies comprise exercises to improve strength of the muscles involved in swallowing, compensatory postures or therapeutic maneuvers, and dietary modification such as manipulating food texture and drink consistency. Among those treatments, dietary modification is the key component of treatment in dysphagia (Curran & Groher, 1990; Martin, 1991; Pardoe, 1993). Diet modification is an effective method to change the texture of food and the viscosity of liquids to compensate for patients' swallowing disorders.

Liquid modification is a complex area where no standardized procedure has been developed in the current system of dysphagia management. Liquid modification is achieved by adding and mixing various forms of thickeners into base drinks to reach different levels of viscosity. Commonly, subjective measurement is used across different facilities and home environments. Yet, this subjective measurement is not an accurate and scientific method so it results in inconsistent viscosity in thickened liquids. Different professions may thicken liquids in different ways. Even internal consistency for the same individual is poor. (Glassburn & Deem, 1998; Steele, Van Lieshout, & Goff, 2003; Cichiero, Jackson, Halley, & Murdoch, 2000a). There is no doubt that the viscosity of the liquid plays a critical role in preventing a bolus from slipping into the airway before the laryngeal system is ready to close off the glottis. When the bolus viscosity is increased, motility of the bolus is decreased and chances of aspiration are reduced.

Logemann (1998) recommended that patients with dysphagia who aspirate more than 10 percent of a bolus of a particular food consistency should be restricted from eating that consistency by mouth. This recommendation underscores the importance of monitoring the viscosity of food and liquids. In turn, the recommendation places a demand for the use of an objective measurement, which can be practically used during evaluation and treatment of patients with dysphagia. Goulding (2000) advocated the importance of monitoring fluid thickness in dietary management, stating that "the patient group provided with optimal fluid thickness monitored by a viscometer may have a better prognosis than the control group who had been given subjectively measured thickened fluid" (p. 124). Additionally, according to Logemann (1998), it is known that there are a substantial number of silent aspirators (patients who aspirate without a cough response). Even experienced clinicians fail to identify approximately 40 percent of patients who aspirate during a bedside examination. Therefore, if food with an inadequate level of viscosity is provided during the mealtime to silent aspirators, it is not likely to be identified. Thus, estimating liquid consistency thickened by a subjective measurement can not prevent aspiration, and it can not promise successful dysphagia treatment.

A standardized method to measure the viscosity of thickened liquids has yet to be developed and examined in medical settings or the home environment. Use of a viscometer is a common method to measure viscosity of fluids in research about dysphagia. A viscometer is an instrument that can measure the viscosity of flow properties. Monitoring fluid with a viscometer is not clinically realistic. Because of the cost of a viscometer, few facilities can utilize a viscometer during every mealtime. For that reason, a subjective measurement of the thickening procedure is still most commonly used by health care professionals and patients' family members.

The subjective measurement in the thickening process refers to judgment of the viscosity by a person's impressions of liquids consistency. This judgment is usually made by observing stirring resistance, oral manipulation, and/or vessel weight. Yet, this subjective measurement is not a reliable method. Subjective measurement can give only a relative physical impression about viscosity. Steele et al. (2003) found that judgment by vessel weight was not highly accurate (67 percent accuracy) when comparing relative thickness between nectar and honey-thick fluid. Although stirring resistance and oral manipulation judgment had 100 percent accuracy on comparing two liquids, this subjective judgment did not enable people who provided dysphagia treatment to mix optimal viscosity of the thickened liquids. Glassburn & Deem (1990) found that speech-language pathologists (SLPs) were not consistent in their attempts to thicken liquids using subjective measurement. They also suggested the need for a standardized procedure for mixing consistencies for evaluations and treatment. A cost effective, easy-to-operate, and portable method needs to be developed and proved to be reliable to use as a standardized procedure of thickening liquids.

Paik, Han, Park, Lee, Park, & Hwang (2004) and Mann and Wong (1996) studied the reliability of the line spread test (LST) compared to a viscometer and a sensory panel (a trained texture profile panel of individuals who subjectively rate the viscosity of the liquids).The LST is an easy, portable, and cost-effective tool that measures how far liquids flow. Thick liquids flow less far than thin liquids. The measurements (centiPoise) from the viscometer were inversely related to the distance that the liquids flow. The viscometer is an instrument that measures the viscosity of fluid. Viscosity is the "tendency to resist flow" (Coster & Schwartz, 1987, p.115). This tendency is defined as the ratio of shear stress. Shear stress is "the force per unit area applied to the fluid" (Cichero, 2006, p. 3). The thinnest liquids have the highest LST value and lowest viscometer value in centiPoise (cP). The sensory panel's ratings for a given thickened liquid agreed with the LST measures (Mann and Wong, 1996), indicating a positive linear relationship (r=.90 to .96). The more thickener that was added to the samples, the smaller the LST values and the lower the ratings of the sensory panel judges.

The dysphagia management team may include patients, family members, and related professionals such as speech-language pathologists, dietitians, nursing staff, physicians, occupational therapists, physical therapists, pharmacists, and radiologists. It is obvious that a systematic, standardized, and objective procedure that is to be utilized by these various groups is required in order to provide improved service to patients with dysphagia. The LST is not used yet in clinical setting in dysphagia management. Research to study the practical impressions of health professionals and family members to the LST will be meaningful to examine the possibility of utilizing the LST in clinical dysphagia management.

Purpose of Investigation

The objectives of this study were twofold: (1) To investigate the reliability of the LST as used by different health care professionals and family members who are related to patients with dysphagia. The hypothesis is that majority of participants should be able to monitor the viscosity of liquids and to produce consistent thickened liquids across different base drinks using the LST; and (2) to investigate potential utilization of the LST in facilities or home environments by questionnaires that are designed to examine participants' impressions about the LST and their perception of its utilization.

CHAPTER 2

LITERATURE REVIEW

Effects of Consistency in Swallowing

The normal adult swallow occurs in four phases: oral preparatory, oral, pharyngeal, and esophageal (Shipley and McAfee, 1998). During the oral preparatory phase, food or liquid is manipulated in the oral cavity, chewed, and made into a bolus. In the oral phase, the bolus is moved to the back of the mouth by the tongue. The swallow reflex is triggered at the point when the bolus hits the anterior faucial pillars and is carried through the pharynx. This portion of the swallowing is called the pharyngeal phase. During the esophageal phase, the bolus is transported through the esophagus into the stomach. The first three phases are of most importance to speech-language pathologists, as well as the influence of bolus consistency on the swallow.

The term “viscosity” is clinically used to refer to thickness and/or consistency of liquid in dysphagia treatment. Viscosity is a measure of the intrinsic ability of fluid to resist flow under force and is quantified as the ratio of shear-stress (stress transmitted by a fluid) to shear-rate (rate of fluid material deformation) (Mills, 2006; Cichero, 2006). Viscosity for dysphagia management is related to the “thickness” of liquids. Thick liquids have a pudding-like consistency and thin liquids contain more water. Thin liquids flow faster and respond quickly and easily to subtle forces and pressure from muscle contractions along the upper digestive tract. Thick liquids travel more slowly from the mouth into the pharynx and are less influenced by those forces and pressures because of their high intrinsic resistance force.

Changing bolus consistency influences temporal aspects not only in the oral phase of swallowing but also in the pharyngeal and esophageal phases (Mills, 2006). Kulemeier and Rogenberg (2001) stated that food viscosity affected the duration of tongue base/posterior pharyngeal wall contact, oral and pharyngeal transit times, pharyngeal delay times, the duration of peristaltic waves, the velocity of esophageal peristaltic waves, the duration of upper esophageal segment opening, and average electromyography (EMG) activity. Changing bolus consistency led to changes in the magnitude of submental EMG activity (from the anterior belly of the digastric muscle, the mylohyoid muscle, and the geniohyoid muscle) (Reimers-Neils, Logemann, & Larson, 1994; Dantas, Dodds, Massey, & Kern, 1989; Ruark, McCullough, Peter, & Moore, 2002; Goulding, 2000).

In an investigation by Ding, Logemann, Larson, & Rademaker (2003), younger (18 to 28 years old) and older (65 to 85 years old) adults with normal swallowing were compared by measuring muscle activities from the oral and pharyngeal phases of swallowing different liquid consistencies. Measurements were taken on surface (EMG) signals from the orbicularis oris inferior region (OOI), the submental muscle group region that includes the anterior belly of the digastric muscle, the mylohyoid muscle, and the geniohyoid muscle, and the infrahyoid muscle group region that includes omohyoid and sternohyoid muscles. Although results indicated that the submental start time was longer in the older group compared to the younger group, there was a significant consistency effect on the submental and infrahyoid start time across the age groups. As the consistency of the liquids swallowed got thicker, researchers observed increased amplitude and duration in submental and infrahyoid activity, increased oral pressures generated by increased submental muscles, and greater laryngeal elevation and depression.

This finding is consistent with Ruark et al.'s (2002) research. They examined the average duration of submental and laryngeal strip muscle activity. Submental muscles targeted were the right and left anterior bellies of the digastric muscle, and for the laryngeal strip, the right thyrohyoid muscle was targeted. Results showed that muscle activities in both children and adults were significantly affected by bolus consistency. Muscle activity systematically increased as the participants swallowed boluses that increased in consistency.

The evidence of the temporal effect of bolus consistency was also found in a study by Hiss, Strauss, Treole, Stuart, & Boutilier (2004) that assessed swallowing apnea (SA) onset time in normal swallowing. SA is the cessation of respiration that occurs with swallowing. These researchers demonstrated that the consistency of the bolus had a significant effect on SA onset time. If SA onset is delayed relative to lingual bolus propulsion, the bolus may proceed into the pharynx during inspiration/expiration. Therefore, subsequent aspiration may occur. In this study, when the viscosity of the bolus was increased, SA onset was delayed.

The effect of viscosity of the bolus also can be shown during a videofluoroscopic swallow study (VFSS). VFSS is a functional test that assesses the swallowing mechanism using x-rays and identifies aspiration and other abnormalities of swallowing. Dantas et al. (1989) investigated the effect of barium sulfate density and viscosity on swallowing during the VFSS. Compared with low-density barium boluses, the high-density barium boluses were associated with later sphincter opening and closure, longer duration of sphincter opening and flow, lower flow rate, greater maximal anterior hyoid movement, greater sagittal sphincter diameter, and higher intrabolus pressure upstream of and within the sphincter. From this study, it was found that the viscosity of the barium sulfate used in the VFSS for the oral-pharyngeal phases of swallowing had an influence on bolus transit time through the mouth and pharynx and on the features of the upper esophageal sphincter opening.

Bolus consistency affects dehydration and malnutrition. Thickened liquids with higher viscosity contain less water compared to the same amount of non-thickened liquids. The more viscous a liquid, the harder patients work to drink. Goulding (2000) divided participants into a study group (n=23) and a control group (n=23). The study group received fluid measured by a viscometer to keep consistent viscosity of the liquid, whereas the control group received fluids subjectively judged by nursing staff. In this study, it was noted that the average viscosity of fluids for the control group had higher viscosity than the study group. Most patients in the control group did not finish their drinks. Goulding also found that thicker liquids have less palatability and higher risk to dehydration than thin liquids.

Wright, Cotter, Hickson, & Frost (2005) investigated dietary intake of older patients (n=30) who received dysphagia diets because of dysphagia (80 percent) or poor dental state (20 percent) compared to older patients (n=25) on normal hospital diets. They found the group receiving the dysphagia diet consumed significantly lower amounts of sugar and protein than those patients on a normal hospital diet. The reasons for this poor intake were related to difficulties in eating and the modified diets. The greater the deformation of food, the less palatable and less presentable it becomes.

Clinicians utilize the effects of consistency to reduce the risk of aspiration. SLPs clinically use thickened liquids for those who have delayed onset of the pharyngeal swallow, impaired oral motor skills, and difficulty controlling thin liquids (Garcia, Chambers, & Molander, 2005). Thickened liquid is also ordered for patients who have reduced airway protection, pharyngeal dysfunction, and reduced oral awareness (O'Gara, 1990).

Goulding (2000) stated that it is not necessarily true that a higher viscosity of liquid is always safer than the lower viscosity of the liquid regarding aspiration rate. Each individual with dysphagia has a different optimal thickness of liquid. After SLPs find the optimal thickness of fluid which can most effectively compensate for each individual's swallowing disorder, patients should be able to receive an individualized diet with constant viscosity of food and drinks.

Clinically, diet modification is considered to reduce aspiration among patients with dysphagia. However, in Goulding's (2000) research, the rate of aspiration from two dysphagic stroke patient groups generated an interesting dilemma. The study results showed that ten patients from the study group whose food was monitored by a viscometer and nine patients from the control group whose food was not monitored had evidence of pulmonary aspiration. There was no significant difference in aspiration occurrences in the two different groups, even though the control group's liquids provided was statistically different from that of study group in terms of the levels of viscosity. This result raises questions about the effectiveness of diet-modification treatment. The potential non-compliance with diet-modification programs for patients is broadly due to two factors. One is a difficulty in matching viscosity of barium sulfate liquid used during VFSS to treatment food, and the other is difficulty in providing constant level of viscosity of food and liquids to patients during mealtime (Cichero et al., 2000a, 2000b; Goulding, 2000; Glassburn and Deem, 1998).

Complications in Thickened Liquid Management

Terminology and standardized procedure.

Throughout the research on thickened liquid management, it was observed that the terms to describe the thickness of fluids are different across countries, facilities, and clinicians. Moreover, there was no standardized procedure for dealing with commercial thickeners in terms of how much to add, how long to wait before drinking, and how to measure the thickness of liquids. Despite the effort to develop categorizations for stages of diet modification in facilities and the effort of manufacturers of thickening agents to provide guidelines to use their products, using diverse terms and non-standardized procedures to make thickened liquid may confuse health care professionals and family members, thus inhibiting patients from receiving consistent presentation of thickened liquids.

The various terms describing thickness throughout the studies cited are “yogurt and syrup” (Goulding, 2000), “thin, nectar-like, honey-like, and spoon-thick” (Tymchuck, 2005), “thin, thick, and ultrathick” (Kulemeier et al., 2001), and “thin, nectar, thin honey, honey, and pudding” (Mills, 2006). In the United Kingdom, “double cream” and “single cream” commonly refer to “honey” and “nectar” terms used in the United States (Macqueen, Taubert, Cotter, Stevens, & Frost, 2003). In Australia, “full thick, half thick, and quarter thick” are used in the classification of thickened liquids (Cichero et al, 2000a, 2000b). None of these descriptions gives information about *how thick* the liquid should be but rather the perception of the thickness. Those perceptual terms produce inconsistent interpretations and impressions.

Because of this confusion about terminology, the National Dysphagia Diet Task Force (2002) set guidelines for acceptable ranges of viscosity in centipoise at a shear rate of 50 s^{-1} viscometrically. The ranges are thin (1 to 50 cP), nectar-like/syrup-like (51-350 cP), honey-like (351 to 1750 cP), and pudding-like/spoon-thick (> 1750 cP) (see Table 1). However, these ranges were determined by a "commonsense approach" (McCullough et al., 2003). When acceptable ranges of the viscosity of the thickened liquid were made based on current practice, there was no scientific support that could prove their effectiveness. In current practice, perceptual terms and subjective judgments are used to describe levels of liquid viscosity. McCullough, Pelletier, & Steele (2003) reported that the National Dysphagia Diet (published in 2002 by the American Dietetic Association) stated that further study and peer-reviewed scientific data were needed to quantify the management parameter surrounding the complex diagnosis of dysphagia.

Table 1

Categorization of Consistencies from National Dysphagia Diet Task Force (2002)

Levels	Thin	Nectar-like/ syrup-like	Honey-like	Pudding-like/spoon-thick
centiPoise (cP)	1-50	51-350	351-1750	> 1750

Notes: From "National Dysphagia Diet: What to Swallow," by McCullough, G., Pelletier, C., and Steele, C., 2003, *The Asha Leader*, 27, p16.

The use of description for a range of consistency levels is also found on the directions for preparing thickened liquids using commercially available powder-type thickeners. For example, using “Thick-it”(Milani Food, Melrose Park, IL), “nectar” consistency requires adding 1 to 2 tablespoons (Tbsp) per 4 ounces of liquid, “honey” consistency has a range of 2 to 3 Tbsp per 4 ounces, and “pudding,

” a range of 3 to 4 Tbsp per 4 ounces. The upper and lower viscosity boundaries in each consistency range are overlapping. Thus, when the order from a speech-language pathologist asks for liquids to be thickened to “honey” consistency, the directions for “Thick-It,” using 2 to 3 Tbsp of thickener would not discriminate “honey” consistency from “nectar” or “pudding” consistency. “Thicken Up” (Novartis, Minneapolis, MN) provides a table that shows how much to add into different types of base drinks. Orange juice, apple juice, cranberry juice, milk, water, and coffee/tea are the examples of the base drinks. For example, with milk and water, to make “nectar-like” consistency, 1 tablespoon and 1 teaspoon (tsp) are needed; 1 Tbsp to 1.5 tsp for “honey-like” consistency, and 2 Tbsp for “pudding” (spoon-thick). But the viscosity for milk at 21°C is 2.1 cP and for water is 1.002 cP. When the viscosity of the base drinks is not the same, mixing with the same amount of the thickener does not necessarily produce the same level of consistency.

Table 2 shows that different dysphagia diet programs have different applications of diet modification. In Curran & Groher’s (1990) model, there are three stages in the diet program and the liquid consistency is also divided into three levels. In Martin’s (1991) model, four levels of diet modification are described. Yet the consistency of the liquid is not clearly differentiated. Pardoe’s (1993) model describes two kinds of liquid (thin and thick), with thin liquid subdivided into two additional thin and thick categories. None of these protocols provide sufficient information of either procedures or accurate viscosity of thickened liquids. Among the three programs, Pardoe's (1993) seems to be easier to understand, because it gives examples of the actual food/drinks.

Table 2

Liquid Classification in Several Diet Modification Programs

Curran & Groher (1990)	
Diet Level	
Nectar consistency	(No description provided)
Honey consistency	
Pudding consistency	
Martin (1991)	
Diet Level	Description
1	No water is allowed. All liquids are thickened with a commercial thicken agent.
2	No water is allowed. Liquids are thickened only as needed with a commercial thickening agent. Patient may begin to drink beverages such as very thick juices and mild products without thickeners, if tolerated.
3	Liquids can be used as tolerated.
4	All liquids are used as tolerated.
Pardoe (1993)	
Diet Level	Description
Liquids	
(1) Thin	Water, all juices thinner than pineapple, Italian ice, other clear liquids except gelatin dessert.
(2) Thick	All other liquids including milk, any juice not classified as a thick liquid, sherbet, ice cream.
Thickened Liquid	Liquids thickened with starch to pureed consistency for those who cannot tolerate any other liquids.

Note: Different dysphagia diet programs have different application of diet modification. None of these gives a clear procedure of the mixing-thickening agent.

Using an accurate description of viscosity rather than the ‘likeliness’ and ‘feeling’ of viscosity is demanded in the field of liquid modification. With ill-defined terms, it is impossible to expect that health care professionals and family members can give consistent thickened liquids to patients at every mealtime. Due to the dependence on subjective and relative terminology and descriptions, it would be difficult to expect to have effective collaboration among personnel on the dysphagia team with regard to thickening liquids.

Variability across commercial thickeners.

Base drinks affect the consistency of thickened liquids across the various commercial powder-type thickeners. The mixture in thicker base drinks will produce thicker liquids than with thin liquids. Thus, the same amount of thickening agent with chocolate milk and apple juice do not produce the same level of viscosity because the original viscosity of the base drinks is different. Similarly, even if orange juice and apple juice are classified as thin liquids (see Table 3), mixtures with the same amount of thickener will produce different thicknesses (Biggs, Cooper, Garcia, & Chamber, 2003; Mills, 1999; Lotong, Chun, Chamber, & Garcia, 2003). The same amount of thickener with orange juice produced more viscous fluid than with apple juice (Biggs et al., 2003). The reason for this is not clear although some chemical characteristics of the base drinks are assumed to have an effect. It is reported that prethickened liquids are more reliable and safer than a powdered corn-starch-based thickener (Cichero, 2006), but they are more expensive. However, even prethickened liquids have different viscosity measurements for nectar and honey consistency over four different commercial products (Nutri-Balance Products, Thick & Easy, Dia-Cry, and Lyons) (Mills, 1999).

Table 3

Categorization of Viscosity for Various Drinks

Consistency Level	Mean Viscosity (cP)	Example of Drinks
Thin liquid	1.0-1.2 cP	coffee, water, tea, clear broth, clear juice, skim milk, 2% milk, whole milk
Thick liquid	56.1 cP	Nectar, tomato juice, buttermilk
Ultra thick	224cP	cream soup

Biggs et al. (2003) and Pelletier (1997) studied time factors for thickening liquids. Biggs et al. measured changes of viscosity with a viscometer at two-minute and ten-minute intervals with orange and apple juice across four brands of powdered thickeners (Thick & Easy, Thick It, Thicken Up, and Thicken Right). Two- and ten-minute intervals were not found to be a significantly different when measuring the viscosity of nectar-thickened juices but were in honey-like juices. This finding is consistent with the data from Pelletier's perceptual rating by four judges. Pelletier measured perceptual ratings of the thickened liquids by four judges on a three-point scale. Judges tested the thickened liquids after 1 to 5 minutes and 17 hours. The time interval factor showed differences in consistency across the five commercial thickeners. Although the research found a significant time effect on viscosity, there was no consistency effect across different commercial powder thickeners.

Reliability among health care professionals.

Glassburn and Deem (1998) tested reliability among speech-language pathologists in making thickened liquids into different levels of consistencies. Twenty-three SLPs, who were experienced in dysphagia management, participated in mixing thickening agents with water into “nectar,” “honey,” and “pudding” consistencies. Results showed that there was poor inter-reliability (among SLPs), although intra-reliability (within SLPs) was relatively higher than inter-reliability. For inter-subject reliability on mixing attempts, the first and second mixing for nectar thickness was $r= -0.02$ and $r= +0.02$, respectively. Similarly for honey thickness, there was no relationship or repeatability between SLPs. Intra-subject reliability for mixing attempts for nectar thickness was $r=+0.26$ for the first trial and $r=+0.33$ for the second trial, showing a weak within-subject relationship. Similar results were found when mixing for honey thickness ($r=+0.67$, first trial; $r=+0.67$, second trial).

Colodny (2001) reported significant noncompliance by nursing staff with SLP recommendations for thickening liquids. Colodny designed a questionnaire to assess the compliance of nursing staff with SLP dysphagia and mealtime feeding recommendations for dependent feeders. Some of the reasons that nurses provided for not complying with the SLP recommendations were the following: “I am not sure how much thickener to use,” “no one showed me how to thicken liquids,” or “it takes a long time to thicken liquids” (p. 267). Difficulty in mixing thickening agents may account for noncompliance.

Additionally, discrepancy in the viscosity of the barium sulfate in the videofluoroscopic swallow study and mealtime liquids was inspected. Cichero et al. (2000a, 2000b) examined viscosity of VFSS fluids and mealtime fluids from ten hospitals in Australia. Each hospital provided 200-ml samples of their range of meal time thickened fluid, and their VFSS counterparts. Samples were classified into “full thin” (slow pourable), “half thick” (smooth yogurt-like), and “quarter thick” (apricot nectar).

The viscosity of each barium sulfate preparation and mealtime fluid was examined. Generally, the VFSS fluids were more viscous than their mealtime counterparts. Results showed that there were quantifiable differences among the viscosity of the thickened fluids provided by different hospitals. Also, within the same hospital, there was variability in the viscosity of the VSFF fluids and the mealtime fluids. Cichero et al. (2000a, 2000b) asserted that variability in intra- (different hospitals) and inter- (VFSS fluid and mealtime fluid within the same hospital) hospital fluid viscosity would affect patients with dysphagia.

Objective Measurement of Liquid Viscosity

The line spread test.

A measurement of viscosity for thickened liquids should be accurate and objective as well as easy to learn, portable, and inexpensive. It has been shown that the line spread test is a reliable method to examine viscosity of fluid compared to using a viscometer (Paik et al., 2004). The LST set is composed of a Plexiglas or glass plate under which concentric circles drawn at intervals of 0.5 cm are placed. An open-ended tube 2 cm in height and 2 cm in diameter is filled with 5 ml of a liquid sample placed in the center of the circles. After the tube is lifted, liquid is allowed to flow for one minute. The distance that the liquid travels is measured at each 90-degree section of the circles and then averaged.

Paik et al. (2004) found that the LST measurement was well correlated with viscometer measurement. There was a significant inverse relationship between the LST scale (cm) and the viscometer scale (cP). As liquids became more viscous, distance from the center was reduced, and on the viscometer, higher cP values were obtained (Table 4).

Table 4

Viscosity Measure of the Liquids with a Viscometer and a LST Tool

Liquids	Viscosity with a viscometer (cP) (shear rate 50 s-1)	LST (cm)
Water	0.9 ± 0.1	5.5 ± 0.5
Diluted barium solution	3.1± 4.8	3.4 ± 0.1
Yogurt	671.0 ± 76.9	2.4 ± 0.1
Pudding	10.031 ± 728	1 cm

Additionally, Mann and Wong (1996) reported that LST measures were well correlated with thickness as judged by a trained sensory panel. The sensory panel judged relative scales in relation to the reference liquids. Importantly, small differences in amounts of thickener produced significant changes in viscosity as measured by both the LST and the sensory panel. These findings suggest that the LST measurement is an accurate and sensitive measurement of viscosity.

Acceptable ranges in LST.

The purpose of using the LST is to monitor the viscosity of thickened liquids. An initial subjective assessment of liquid thickness can be confirmed with the LST. If the LST is not matched with the acceptable range of the intended consistency, clinicians or anyone who makes thickened liquids can add thickening agents or base drinks. Paik et al., (2004) suggested thickness categorization using the LST parameters. Table 5 shows these categorizations of dysphagia diets. The ranges of centiPoise corresponding to the ranges of the LST (cm) in Table 5 are different from those reported in the National Dysphagia Diet Task Force. It is noted that the National Dysphagia Diet Task Force set the guideline based on “common sense approach” rather than by specific measurement (McCullough et al., 2003). Yet, Paik et al. (2004) tested actual food, which represented each level of thickness consistency, to measure the range of LST values.

Table 5

Suggested Categorization of Dysphagia Diets by Food Viscosity

Levels of viscosity by LST (cm)	> 4	3-3.9	1.1-2.9	0-1
Correspondence by viscometer (cP) at shear rate 50 s-1	1-9	10-99	100-9999	>10,000
Food types	water, orange juice, 35% diluted barium solution	yogurt (fluid type), tomato juice, barium solution	honey, yogurt (curd type), orange juice (mixed with 3% food thickener)	pudding

Note: From “Categorization of dysphagia diets with the line spread test,” by Paik et al., 2004, *Archives Physical Medicine and Rehabilitation*, 85, p. 860.

Summary

Changing bolus consistency is one of the most important treatments for patients with dysphagia. Change in the bolus compensates for the abnormality of swallowing by changing motility. Generally, there are three levels of consistency: nectar-like, honey-like, and pudding-like. Without a standardized procedure of mixing thickening agents, these perceptual terms describing levels of consistency do not give the exact thickness of the liquids. Additionally, thickness varies across commercial thickeners and across various conditions, such as different base drinks, persons who mix, and standing time. For this reason, Cichero (2006) suggested that looking at viscosity testing in dysphagia management was like opening Pandora's box. In the area of dysphagia management, the study of controlling the viscosity of thickened liquids has just begun.

In the diet modification program of dysphagia management, the first thing that needs to be studied is objective measurement of bolus consistency. Currently, only subjective measurement is used during the procedure of mixing thickening agents. Yet, subjective judgments, such as stirring-resistance, oral manipulation, and vessel weight, are not reliable (Glassburn and Deem, 1998). An objective measurement needs to be utilized in facilities and home environments. Although a viscometer is one of the most reliable tools for measuring viscosity, it is not readily available in clinical settings. Paik et al. (2004) and Mann and Wong (1996) investigated reliability of the line spread test for measuring liquid thickness and found that it is reliable compared to a viscometer and the sensory panel. Use of the LST in clinical settings has not yet been studied.

This study investigated the possibility and reality of using the LST in a clinical setting by asking health care professionals and naïve adults (who possibly have a patient in their care) to use the LST and make three levels of consistency with different base drinks.

Research Questions

This research investigated the validity and usability of the LST by asking five questions:

Question 1. What values are obtained using the LST for different base drinks in different levels of consistency?

Question 2. Are there any differences among base drinks in making thickened liquids and measuring with the LST?

Question 3. How many trials do participants need in order to achieve the “standard” range of nectar and honey consistencies of thickened liquids using the LST?

Question 4. Are there any group differences in using the LST according to each group’s professional background?

Question 5. Does the LST tool help people to understand the thickness of liquids?

CHAPTER 3

METHODOLOGY

Participants

Twenty health care professionals (four SLPs, four dietary staff members, four licensed nurses, four registered nurses) and four naïve adults (who might potentially be a family member providing care for someone requiring dysphagia diet) were to be recruited as participants in this study. The health care professionals were to will have had at least two years experience in dysphagia management.

Materials

As base drinks, orange juice, water, Ensure, and 2% milk were chosen. Cold drinks were provided directly out of a refrigerator and left at room temperature during the procedure. Dairy drinks were represented by 2% milk. Water and orange juice are common drinks served at the hospital, and Ensure is often given to patients to meet their requirement for daily nutrition.

Thicken Up (Sandoz Nutrition) was selected as a thickening agent. Garcia et al. (2005) reported that SLPs most frequently selected two brands of powdered thickeners: Thicken Up (Sandoz Nutrition) and Thick It (Milani Foods). However, Pelletier (1997) reported that Thicken Up (Sandoz Nutrition) produced the most consistent thickness across different base drinks (juice, 2% milk, and black coffee) and kept the most stable viscosity as the thickened liquids stood longer.

The investigator prepared two line spread test measurement sets and an LST measurement chart (Appendix A). A LST measurement set (Figure 1) consisted of a glass plate, a grid with premeasured concentric circles (0.5 cm intervals), an open-ended tube

(2 cm in height, 2 cm in diameter), and a syringe that had indications of 5 ml levels. The investigator had a timer, a calculator, and a carpenter's level.

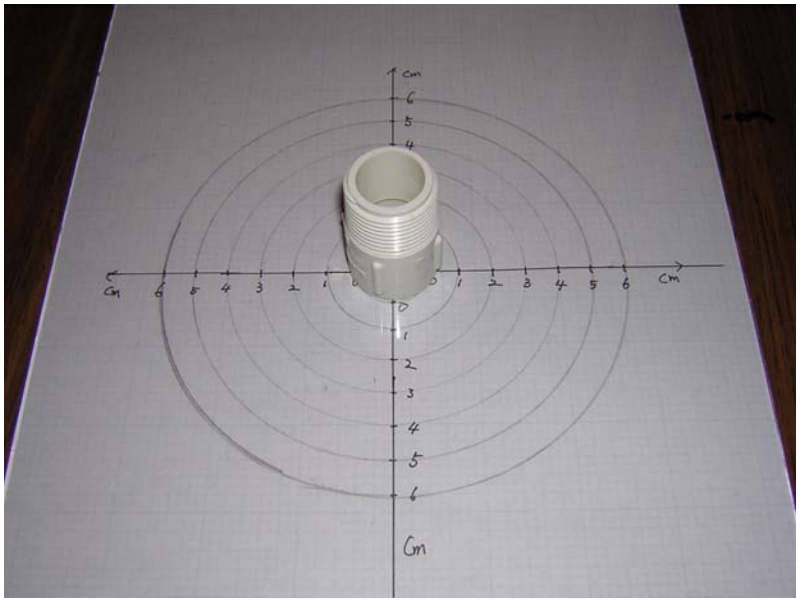


Figure 1. LST tool set showing 1-cm interval concentric circled grid under a glass plate and a 1 cm diameter open-ended tube.

Procedures

After participants were contacted by telephone, they were asked to come to Wichita State University, or the investigator visited the participants' facilities or home. Each participant performed the LST experiment individually so they did not communicate and influence each other during the experiment.

Each participant made thickened liquids with water, orange juice, 2% milk, and Ensure in nectar and honey consistency in random order, for a total of eight thickened liquids.

Each participant followed this sequence:

(1) To the health care professionals, the investigator explained that the LST method was an objective measurement of viscosity of thickened liquid. It subjectively confirmed the measured consistency of thickened liquids.

To naïve adults, the investigator explained the three consistencies of thickened liquids: nectar, honey, and pudding-like. The investigator showed a cup of apricot nectar and a half cup of honey to help the naïve adults understand the concept of liquid consistency.

(2) The investigator showed an LST tool and explained the acceptable ranges in centimeters for nectar and honey consistency.

(3) Using a carpenter's level, the investigator checked the level of the table where LST sets were placed.

(4) Participants mixed Thicken Up (Sandoz Nutrition) to a base drink to an intended consistency using subjective judgment.

(5) The investigator counted two minutes of waiting time per manufacturer's instructions. If more thickening agent was added, waiting time was increased another two minutes.

(6) Participants placed two open-ended tubes on two glass plates and filled each with 5 ml of the thickened liquids using a syringe.

(7) Participants lifted the tubes and waited one minute for flow.

(8) The investigator read the numbers in four 90-degree sections of the concentric circles underneath a glass plate and then averaged them. This procedure was repeated on the second glass plate, as needed.

(9) The investigator recorded the LST values from the two glass plates and averaged them.

(10) Initial trial: If the averaged LST met the acceptable range (see Table 5), the participant randomly chose the next base drinks and consistency, and performed the same procedure. Modification trial: If unable to reach the acceptable range, participants added thickening agents or base drinks to the thickened liquids to modify consistency. The investigator measured the new LST value (the first modification trial). If the procedure failed again, participants performed the modification procedure again (the second modification trial). There was no third modification trial.

(11) After finishing LST measurements, participants filled out the questionnaires (Appendix B for health care professionals and Appendix C for naïve adults).

CHAPTER 4

RESULTS

Calibration of LST tool

Prior to recruiting participants, the investigator measured the line spread test value of water, apricot nectar, and real honey with the LST tool following Paik et al.'s (2004) model. Table 6 shows the LST values obtained for water, apricot, and honey. These mean LST values met Paik et al.'s acceptable ranges (Table 5).

Table 6

Calibration Measures for Base Liquids (in cm)

	Trial 1	Trial 2	Trial 3	Trial 4	Mean LST	**Paik et al.'s Range**
Water	5.23	5.96	5.67	5.15	5.50	> **4**
Apricot Nectar	3.27	3.27	4.20	4.02	3.69	**3-3.9**
Honey	2.45	2.47	2.46	2.50	2.74	**1.1-2.9**

Note: The value of each drink matched with Paik et al.'s (2004) values.

Thickened Liquids by Naïve Adults

Three naïve adults participated in the experiment initially. The average age of these three participants was 53.3 years, and all were female. Results of the experiment for each participant are shown in Appendices D, E, and F. A total of 24 trials were obtained from the three participants, which included making nectar and honey consistencies in water, orange juice, 2% milk, and Ensure (2 consistencies x 4 base drinks x 3 participants). Out of 12 trials of nectar consistency of thickened liquids, nine trials required the first and second modification trials, yet failed to meet the acceptable range. Out of 12 trials of honey consistency of thickened liquids, ten trials succeeded. One trial succeeded at the first modification trial, and the other failed at the second modification trial (Table 7). None of the three participants succeeded in making nectar consistency liquids with orange juice and Ensure, even in two modification trials. In contrast, all of them did well with the honey consistency.

None of the thickened liquids prepared by any of three participants met Paik et al.'s (2004) acceptable range for thickened liquids of nectar consistency. From this preliminary data, the clinical validity issue about this LST tool arose and provided a question as to whether to proceed with the experiment as designed. At this point, the investigator needed to know if the LST protocol could be replicated for acceptable values for the base drinks.

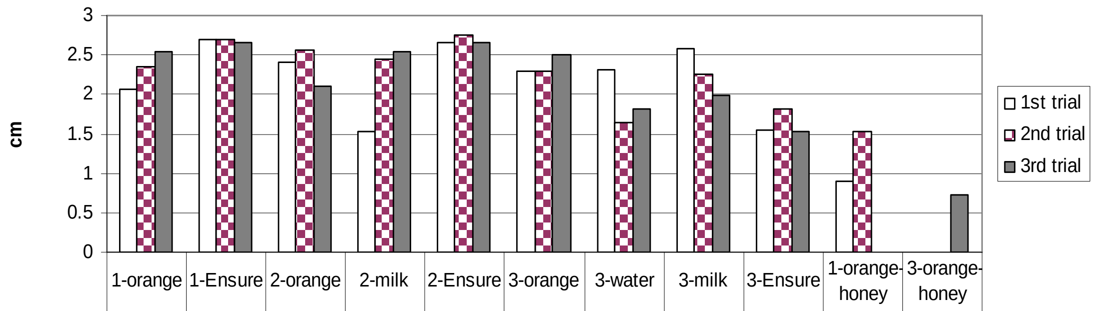
The pattern of LST value changes over the initial trial and the first and second modification procedure, as shown in Figure 2. Even if all participants added base drinks and no thickeners, LST values did not consistently increase in all cases. In only four cases of modification (participant 1 with orange nectar liquid and participant 2 with 2% milk nectar, and all honey liquids) were gradual increases of the LST value shown.

TABLE 7

The LST Value in Modification Procedure

Consistency	Participant	Base drink	Trial	1^{st} modification (in centimeter)	2^{nd} modification	Fail: X Success: O
Nectar	Par. 1	Orange juice	2.06	2.35	2.55	X
		Water	3.40			O
		2% milk	3.00			O
		Ensure	2.70	2.70	2.65	X
	Par. 2	Orange juice	2.41	2.56	2.11	X
		Water	3.20			O
		2% milk	1.53	2.45	2.55	X
		Ensure	2.65	2.75	2.65	X
	Par. 3	Orange juice	2.29	2.30	2.50	X
		Water	2.31	1.64	1.81	X
		2% milk	2.58	2.25	1.99	X
		Ensure	1.54	1.82	1.52	X
Honey	Par. 1	Orange juice	0.90	1.53		O
		Water	2.40			O
		2% milk	2.20			O
		Ensure	2.15			O
	Par. 2	Orange Juice	1.47			O
		Water	1.59			O
		2% milk	1.49			O
		Ensure	1.90			O
	Par. 3	Orange juice	0.00*	0.00*	0.73	X
		Water	1.48			O
		2% milk	1.10			O
		Ensure	1.88			O

Note: Participant 3 achieved '0 cm' with honey-thick orange juice. The thickened liquid was too thick to spread after lifting up the open-ended tube on the plate.



	1-orange	1-Ensure	2-orange	2-milk	2-Ensure	3-orange	3-water	3-milk	3-Ensure	1-orange-honey	3-orange-honey
1st trial	2.06	2.7	2.41	1.53	2.65	2.29	2.31	2.58	1.54	0.9	0
2nd trial	2.35	2.7	2.56	2.45	2.75	2.3	1.64	2.25	1.82	1.53	0
3rd trial	2.55	2.65	2.11	2.55	2.65	2.5	1.81	1.99	1.52		0.73

case

Figure 2. Changes of LST values in trials: The first nine cases are nectar consistency, and the last two cases are honey consistency. Numbers before the base drinks represent participant 1, 2, and 3. All nectar consistency liquids failed at the 3rd trial; 1-orange-honey succeeded at the 2nd trial, and 3-orange-honey at the 3rd trial.

New Research Questions and Modified Research Methodology

New research questions.

New research questions were determined and the methodology was modified. These new questions follow:

1. What are the LST values with pure base drinks: water, orange juice, apple juice, 2% milk, and Ensure?
2. Do the obtained LST values consistently match with Paik et al.'s (2004) established LST values?
3. What are the variables that potentially cause the change in LST values?
    a. Does the time of day for performing the LST affect LST values?
    b. Do different types of plates used in a LST tool kit result in different LST values?

c. Does the person who pours the liquids and lifts up the open-ended tube make a difference in LST values?

Modified methodology.

To answer the new research questions, the investigator chose two kinds of plates—one glass and the other Plexiglas. Four glass plates were randomly labeled A-1, A-2, A-3, and A-4. The glass plates were from picture frames 8.5 inch by 11 inch in size. Plexiglas plates, 6 inch by 6 inch, were cut from a larger section. These were labeled B-1 or B-2. Only these labeled plates were used during the modified experiment. Five base drinks were used in this modified experiment: water, orange juice, apple juice, 2% milk, and Ensure.

The investigator measured LST values for base drinks during morning and afternoon times over three days. Four naïve adults and six speech-language pathologists were recruited and performed the LST protocol on the glass and Plexiglas plates while the investigator read the distance the liquids flowed.

Base drinks were brought directly from the refrigerator at the beginning of each session, poured into transparent plastic cups, and left at room temperature during the procedure. The investigator introduced the LST tool to the participants. Then, the participants were asked to inject 5 ml of a pure drink into the 2 cm in diameter open-ended tube on the six plates using a syringe. Participants poured one each of drink on the six plates (4 glass plates and 2 Plexiglas plates) and the investigator read the values of the drink on the concentric circles after one minute of flow. The order of based drinks measured was water, apple juice, orange juice, 2% milk, and then Ensure. A separate syringe and tube were used only for each base drink. To avoid washing glass plates during the procedure, the first three liquids were measured in separate areas on the one side of the glass plate, and the next two liquids were measured in separate areas on the other side of the glass plates. Ten different Plexiglas plates were used for each session (two for each base drink). Between sessions, all plates were washed only with water without detergent and dried in the air.

Data Analysis

The LST values of pure drinks.

The mean LST values of each base drink from the investigator and two participant groups were calculated (Table 8). Each pure drink had different LST values on the glass plate and the Plexiglas plate. The average LST value of water on the glass plate was 2.02 cm. This value was lower than the 5. 5 cm in Paik et al.'s (2004) data (see Table 4) and in the investigator's calibration measurement (see Table 6). According to Paik et al.'s categorization (Table 6), all the obtained LST values of the base drinks (water, apple juice, orange juice, 2% milk, and Ensure) fall into honey-like consistency. Among five drinks, water had the lowest LST value (2.02 cm) and Ensure had the highest LST value (2.3 cm) measured on the glass plate LST tool.

One way ANOVA was performed, comparing mean LST values of liquids on the glass plates and Plexiglas plates separately. A significant difference was found among liquids on the glass plates ($F(4,55)=5.013$, $p< .05$). A Tukey post hoc analysis was conducted and revealed that the LST value of 2% milk was significantly different from water, apple juice, and orange juice. Also, a significant difference was found among liquids on Plexiglas ($F(4,25)=4.304$, $p< .05$). A Tukey post hoc analysis revealed that only water and Ensure had significantly different LST values (Table 9).

Overall, on the glass plate, water, apple juice, orange juice, and Ensure had similar LST values. Also, Ensure and 2% milk consistencies were not differentiated by the LST measurement. On the Plexiglas plates, water, apple juice, orange juice, and 2% milk were different from Ensure.

Table 8

Mean LST Value of Five Pure Drinks

Plate	Liquids	Mean (cm)	Std. Deviation	N
Glass	water	2.02	.31	12
	apple juice	2.02	.22	12
	orange juice	2.08	.21	12
	2% milk	2.39	.31	12
	Ensure	2.30	.2	12
Plexiglas	water	1.21	.13	6
	apple juice	1.28	.18	6
	orange juice	1.50	.27	6
	2% milk	1.48	.09	6
	Ensure	1.54	.12	6

Table 9

Tukey Post Hoc Test for Mean LST Values

Liquids		Glass Plate Mean Difference	Glass Plate Sig.	Plexiglas Plate Mean Difference	Plexiglas Plate Sig.
Water	Apple juice	.00083	1.000	-.06833	.958
	Orange juice	-.06083	.981	-.29000	.053
	2% milk	-.37833	**.010***	-.27167	.078
	Ensure	-.28167	.095	-.32333	**.025***
Apple juice	Water	-.00083	1.000	.06833	.958
	Orange juice	-.06167	.980	-.22167	.203
	2% milk	-.37917	**.010***	-.20333	.276
	Ensure	-.28250	.093	-.25500	.109
Orange juice	Water	.06083	.981	.29000	.053
	Apple juice	.06167	.980	.22167	.203
	2% milk	-.31750	**.044***	.01833	1.000
	Ensure	-.22083	.281	-.03333	.997
2% milk	Water	.37833	**.010***	.27167	.078
	Apple juice	.37917	**.010***	.20333	.276
	Orange juice	.31750	**.044***	-.01833	1.000
	Ensure	.09667	.905	-.05167	.985
Ensure	Water	.28167	.095	.32333	**.025***
	Apple juice	.28250	.093	.25500	.109
	Orange juice	.22083	.281	.03333	.997
	2% milk	-.09667	.905	.05167	.985

* $p < .05$

Time of day and plate difference.

The raw LST data achieved by the investigator (Appendix J) was measured in the morning and the afternoon over three days. The mean LST values of pure drinks on the glass plate and Plexiglas are shown in Table 10.

A 2 (times during day) x 2 (plates) between-subjects factorial ANOVA was calculated comparing the LST values of each pure drink (Table 11). The Main effect for time of day was not significant in water ($F(1,8)=.495$, $p > .05$), apple juice ($F(1,8)=.444$, p> .05), orange juice (F(1,8)=1.696, p> .05), and 2% milk (F(1,8)=.395, p> .05), but was significant in Ensure (F(1,8)=6.067, p< .05). As shown in Table 10, the LST values on the glass plate decreased in the afternoon, and the LST values on the Plexiglas plate were equal or increased in the afternoon.

Table 10

Means and Standard Deviations on LST Values of Pure Drinks by Time of Day and Plate

Drink	Plate	Morning		Afternoon	
		Mean (cm)	SD	Mean (cm)	SD
Water	Glass	2.10	.18	1.73	.12
	Plexiglas	1.20	.00	1.39	.45
Apple juice	Glass	2.29	.79	1.78	.08
	Plexiglas	1.43	.22	1.53	.15
Orange juice	Glass	2.41	.43	1.95	.21
	Plexiglas	1.49	.06	1.48	.02
2% Milk	Glass	2.65	.45	2.28	.49
	Plexiglas	1.56	.13	1.61	.05
Ensure	Glass	2.70	.24	2.19	.06
	Plexiglas	1.67	.08	1.71	.00

The significant main effect for the plate was found in water (F(1,8)=22.581, p< .05), orange juice (F(1,8)=14.417, p< .05), 2% milk (F(1,8)=12.158, p< .05), and Ensure (F(1,8)=63.034, p< .05). No significant effect for the plate was found in apple juice (F(1,8)=3.258, p> .05). All the LST values of the pure drinks on the glass plate were lower than on the Plexiglas plate.

Table 11

Test Between Subjects of Effects by Two Independent Variables (plate and time of day)

	Water		Apple juice		Orange juice		2% Milk		Ensure	
	F (1,8)	Sig.	F(1,8)	Sig.	F (1,8)	Sig.	F (1,8)	Sig.	F (1,8)	Sig.
Plate	22.581	**.001***	3.258	.109	14.417	**.005***	12.158	**.008***	63.034	**.000***
Time	.495	.502	.444	.524	1.696	.229	.395	.547	6.067	**.039***

* $p < .05$

Group and plate difference.

Two groups (four naïve adults and six SLPs) participated in the LST measurement. Raw LST data from each group are found in Appendices K and L. Descriptive data is shown in Table 12.

Table 12

Means and Standard Deviations on LST Values of Pure Drinks by Group and Plate

Drink	Plate	Naïve Adults			SLPs		
		N	M (cm)	SD	N	M (cm)	SD
Water	Glass	4	2.17	.39	4	2.11	.17
	Plexiglas	2	1.23	.05	2	1.12	.00
Apple juice	Glass	4	2.05	.10	4	1.97	.12
	Plexiglas	2	1.20	.04	2	1.17	.07
Orange juice	Glass	4	1.96	.23	4	2.09	.08
	Plexiglas	2	1.33	.02	2	1.69	.48
2% Milk	Glass	4	2.09	.12	4	2.63	.13
	Plexiglas	2	1.47	.00	2	1.41	.02
Ensure	Glass	4	2.04	.15	4	2.41	.30
	Plexiglas	2	1.42	.01	2	1.51	.02

A 2 (groups) x 2 (plates) between-subjects factorial ANOVA was calculated comparing the LST values of each pure drink (Table 13). The main effect for group was not significant in water ($F(1,8)=.287$, $p > .05$), apple juice ($F(1,8)=.749$, $p > .05$), orange juice ($F(1,8)=2.986$, $p > .05$), and Ensure ($F(1,8)=3.168$, $p > .05$), but it was significant in 2% milk ($F(1,8)=12.520$, $p < .05$). Overall, there was no real group effect on LST values.

A significant main effect for the plate was found across all drinks: water ($F(1,8)=36.432$, $p < .05$), apple juice ($F(1,8)=169.566$, $p < .05$), orange juice ($F(1,8)=13.324$, $p < .05$), 2% milk ($F(1,8)=18.355$, $p < .05$), and Ensure ($F(1,8)=36.104$, $p < .05$). In this study, all LST values of the base drinks were higher on the glass plate compared to those on the Plexiglas plate from both groups. The differences between these LST values on different plates were significantly different. All of the pure drinks spread further on the glass plate than on the Plexiglas plate.

Table 13

Test Between Subjects of Effects by Two Independent Variables (plate and group)

	Water		Apple juice		Orange juice		2% Milk		Ensure	
	F (1,8)	Sig.	F(1,8)	Sig.	F (1,8)	Sig.	F (1,8)	Sig.	F (1,8)	Sig.
Plate	36.432	**.000***	169.566	**.000***	13.324	**.006***	183.555	**.000***	36.104	**.000***
Group	.287	.607	.749	.412	2.986	.122	12.520	**.008***	3.168	.113

* p< .05

CHAPTER 5

DISCUSSION

Original Research: Thickened Liquids

This investigation was based on the findings of Paik et al.'s (2004) research, the measurement of liquid consistency using an LST tool. This study was planned to validate the line spread test method and to examine the possibility of using an LST tool in a clinical setting.

LST values of the thickened liquids.

Attempting nectar, the LST values hardly exceeded 3 cm when nectar consistency was reported to be 3 to 3.9 cm (Paik et al., 2004). Attempting honey, the LST values were limited to fewer than 2 cm, meeting the acceptable range of honey consistency, that is, 1.1 to 2.9 cm (Paik et al., 2004). Regardless of consistency of the thickened liquids, overall LST values ranged from 2 to 3 cm. The results of LST values of the nectar-consistency liquids were far below Paik et al.'s (2004) range and even fell into the range of honey consistency.

Among the four base drinks—orange juice, water, 2% milk, and Ensure—none of the participants succeeded in thickened liquids to acceptable nectar consistency with orange juice and Ensure, even following two modification trials. This might suggest that orange juice and Ensure, as pure drinks, are already near nectar consistency. However, from Paik et al.'s (2004) study, water and orange juice were determined as thin liquids by viscometer measurement (see Table 5).

There are noticeable differences between the LST values of honey consistency and nectar consistency of the thickened liquids. Liquids thickened with water, orange juice, and 2% milk have about 0.9 cm and Ensure has about 0.3 cm of difference between nectar and honey consistency. These differences in the LST value in nectar and honey-thick thickened liquids were determined by comparing the last trial of the LST measurement of each thickened liquid. Differences of 0.9 cm and 0.3 cm between nectar and honey consistency were trivial. Even when the investigator measured the LST values of pure drinks over three days, water ranged from 1.21 to 3.31 cm (Table 10).

Modification trials for thickened liquids.

The investigator hypothesized that the participant would be able to modify the thickened liquids using an LST tool during two modification trials when they failed at the initial trial. The LST tool, at least the one assembled for this research, was not able to provide any reference for the modification or result in any consistent LST values across the trials. One of the complications in thickened liquid treatment is unstable viscosity. Most thickening powders result in changing the viscosity of the liquids the longer they stand. All participants were trying to increase the LST values during the modification trials. They added only base drinks. Theoretically, the LST value should have only increased. But the LST value either increased or decreased over the trials without any certain pattern of change. It is hard to say if the quality of the thickening agent caused this or if the LST measurement was not consistent across the several trials performed.

In sum, the LST tool did not make the measurement of the modified of thickened liquids any easier. Participants were not able to successfully modify the thickened liquids based on the reference values. When participants failed at the initial trial, they also failed at the first and second modification trial except for one time in honey consistency in which a participant succeeded at the first modification trial.

Participants' understanding of LST measurement.

The three participants filled out the questionnaire (Appendices H, I, and J), and all reported that they understood well the concept of different consistencies and the acceptable ranges of each consistency. All participants seemed to understand the concept "thicker liquids flow less than the thin liquids."

All of them answered that the LST tool was easy to operate. Two of them answered that they would rather make thickened liquids by sight only instead of confirming with an LST tool. Participant 1 revealed concerns about the time-consuming procedures of the LST and the nature of thickened liquids that get thicker as they stand longer. Participant 2 stated that the acceptable range was too wide. Participant 3 mentioned difficulty in modifying the thickened liquids once they failed to meet the acceptable range at the first trial.

On the questionnaire, to question number 2, "what might be your concern if you have to prepare thicken liquids for a family member?" participant 1 answered "The consistency of the liquid after it settles for 2 minutes. The consistency changes after awhile." During the first two minutes for resolving the thickener and one minute of flowing time, it seemed like the thickened liquids gained thickness.

The Modified Research: Pure Drinks

The hypotheses about the reason that the thickness of thickened liquids were not able to be modified using the LST tool were as follows: (1) the plate of the LST tool is different than Paik et al.'s (2004); (2) the LST tool does not measure the thickness consistently even with the same liquid when measured at a different time; and (3) the person who handles the LST will cause differences.

First of all, when measuring pure base drinks, LST values did not meet the values for thin liquids in Paik et al's categorization. Even the thinnest liquid, water, had a 2.02 cm LST value on average. The thickest drink is Ensure, according to subjective judgment. But the average LST of Ensure was 2.30 cm, which is higher than water and lower than 2% milk (2.39 cm). Similarly, on the Plexiglas plate, water had the lowest LST value, 1.21 cm, while Ensure had the highest, 1.54 cm. The LST values of the pure drinks also did not match with subjective measurement.

Secondly, the LST value was significantly different depending on the types of plate used in the LST tool. Plexiglas produced significantly lower values than glass plates used in the modified study. This might indicate that glass plates used in this experiment were different from what was used in Paik et al.'s (2004) experiment. However, when the investigator calibrated the LST tool, the LST values of water, apricot nectar, and honey met the LST values from Paik et al.'s (2004) classification. The reason that the LST value from the actual experiment was different from what was obtained from calibration procedure is still uncertain. During the cleaning process, no dish detergent or chemical substance was used, only water. Therefore, it is suspected that there could be some chemical substance on the surface of the glass plate remaining on the new plates. That chemical substance, possibly something that helped the glass stay clean, washed off during the cleaning process over the course of the study, and that may have affected inconsistent LST value between the calibration measurements and the actual experiment.

Lastly, statistics showed a significant effect relative to time of day in Ensure but not in the other pure drinks. It could be assumed that there might be no time of day effect to the consistency of liquids. Rather, the increasing and decreasing LST values over the time of the measurement seem to be a sign of inconsistency of the LST tool. Similarly, no significant group effect was found in the LST measurement. Changes on the obtained LST value were likely random.

Conclusions

The investigator found that the LST tool was not a reliable method to measure consistency of thickened liquids. This experiment was empirical, which means its procedure is the same for anyone using the LST tool. Since this experiment did not show consistent data for the thickened liquids and base drinks, it is doubtful that the LST tool could be used in the practical setting of dysphagia treatment. Depending on the plate, the distance that liquids flowed was different. Since the LST value was statistically significantly different, depending on the glass plate and Plexiglas plate used in this experiment, it is assumed that different quality glass plates might cause different results in the LST value.

The difference of the LST values between nectar and honey consistency was 0.9 cm and 0.3 cm, respectively, depending on the pure drinks. This difference is not wide. The LST tool is not sensitive to discriminating nectar and honey consistency clearly.

Also, using the LST tool requires considerable attention to the cleaning and drying process. Since the use of detergent was not recommended, there is a need to be careful to clean liquids from the plates completely and dry parts completely, thereby taking time to be able to use the set again. This could be another weak point of this tool for health care professionals to use in the practical setting. Nurses and speech language pathologists treat many dysphagia patients a day. Especially in the in-patient hospital setting, SLPs travel floor to floor. Using the LST tool set may not be practical in these settings.

Limitations of Study

The investigator had to modify the originally designed method after three naïve adults performed the LST on the thickened liquids. The LST values of the thickened liquids obtained were different from Paik et al.'s (2004) results. Comparing different groups' impressions and performances might provide more information on evaluating and validating a LST tool than to see only naïve adults' performance. If SLPs were experienced with diet modification treatment in dysphagia patients, their impressions and performance would be different from what naïve adults performed and answered on the questionnaire form. The investigator assumes that it might be possible that the naïve adults lost their subjectivity for nectar and honey consistency since the LST failed at the first trial because they had not previously made thickened liquids. That could have caused inconsistency in increasing and decreasing the LST values over the trials. If the SLP group had been used in the comparison, it might be easier to see if the changing LST value was purely due to the inconsistency of the LST method.

The second area that could be improved for this experiment is expanding plate choices. Glass plates and Plexiglas plates were the only types of plates compared, and the LST value was significantly different depending on which plate used. Data analysis showed that different plates can result in significantly different LST values of the pure drinks. Finding different qualities of glass plates and comparing the LST values from two or three of them might explain if the LST method itself is not valid or whether using an LST tool is determined by selecting an appropriate glass plate.

Future Implications

This investigation was undertaken to verify the LST tool as a simpler method to determine the thickness of liquids. This experiment indicated that the LST tool is not a valid and reliable method to measure thickness of liquids, and it cannot help users to modify the thickness of liquids. In the future, to be able to validate the LST the ingredients of the liquids and their effect on the flow on a plate need to be studied. It is not certain how differently the liquids flow if they contain an oil substance versus water-based liquids.

Viscosity is a complex term. It cannot be defined only by the distance that liquid flows. The concept “different levels of consistency always have different flow distance” may be misleading. Can the distance that liquids spread provide a good objective reference to determine consistency of liquids? Does it oversimplify the viscosity and consistency of liquids? In this study, there is no doubt that with subjective judgment Ensure is the thickest liquid among water, apple juice, orange juice, and 2% milk. Yet, Ensure had greater LST values than the other pure drinks. It is uncertain if the oil-based ingredients in Ensure made it flow further on the plate or if Ensure has bigger particles in it that generate less friction on the surface of the plate.

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APPENDICES

APPENDIX A

LST MEASUREMENT CHART

Participant's professional background:

○ SLP ○ dietary staff ○ CNA ○ RN ○ family member

(1) How to measure the LST (cm)
Let the thickened liquids flow on two plates (Plexiglas) at the same time. After one minute, measure distances of 4 angles and get the average of them in each plate. Average the measurements from the two plates.

PLATE 1 *PLATE 2*
{(Add distances of 4 angles ÷ 4 = __ cm) + (Add distance of 4 angles ÷ 4 = __ cm)} ÷ 2 =____ LST (cm)

(2) If you succeed in thickening the liquid to the acceptable range at trial 1, do not perform trial 2 and trial 3.
If you do not succeed at trial 1, modify the liquid and perform trial 2.
If you do not succeed at trial 2, modify the liquid and perform trial 3.

Thickened Liquids		Trial 1				Trial 2				Trial 3			
		Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X
Apple Juice	3-3.9 cm (Nectar)	cm	cm	cm		cm	cm	cm		cm	cm	cm	
	1.1-2.9 cm (honey)	cm	cm	cm		cm	cm	cm		cm	cm	cm	
Water	3~3.9 cm (Nectar)	cm	cm	cm		cm	cm	cm		cm	cm	cm	
	1.1~2.9 cm (honey)	cm	cm	cm		cm	cm	cm		cm	cm	cm	
2% Milk	3~3.9 cm (Nectar)	cm	cm	cm		cm	cm	cm		cm	cm	cm	
	1.1~2.9 cm (honey)	cm	cm	cm		cm	cm	cm		cm	cm	cm	
Orange Juice	3~3.9 cm (Nectar)	N/A cm	N/A cm	N/A cm		N/A cm	N/A cm	N/A cm		N/A cm	N/A cm	N/A cm	
	1.1~2.9 cm (honey)	cm	cm	cm		cm	cm	cm		cm	cm	cm	

*Note: O= Succeed, X= Fail

APPENDIX B

QUESTIONNAIRE FOR HEALTH CARE PROFESSIONALS

1. Professional background
   ○ SLP ○ dietary staff ○ CNA ○ RN
2. How long have you worked with patients with dysphagia? ______________yrs
3. Who in your facility typically thickens liquids for patient? _________________
4. How do you normally measure thickness of liquids?
   ○ using a viscometer
   ○ subjective judgment by stirring, tasting, and/or oral manipulation, etc.
   ○ using the LST
5. How were you taught to thicken liquids? (including terms, how long, from whom, etc.)
   ____
   ____
6. How do you teach other professions?
   ____
   ____
7. Is the range of the LST understandable and acceptable for you and why?
   ○ Yes. ○ No. (Why?____)

8. Do you think you will use the LST when you see patients?
   ○ Yes. ○ No.

   If yes, why? (you can check more than one)
   ○ able to make accurate thickness of the liquids
   ○ cheap to have one
   ○ portable
   ○ takes short time to operate
   ○ helps to explain to other people how thick it is.
   ○ confirms the thickened liquids that I made whether it is the right level of consistency.
   ○ Any other reasons? ______________________________________

   If no, why? (you can check more than one)
   ○ It takes a long time to measure the LST. I am afraid we don't have much time.
   ○ I don't think I can bring a LST set every time that I meet patients.
   ○ It is hard to read numbers and to do the math.
   ○ I don't think it is accurate.
   ○ My subjective measurement is good enough.
   ○ Any other reasons? ____

9. If you have any comment and suggestions about thickening liquid, please address them here. ____

APPENDIX C

QUESTIONNAIRE FOR FAMILY MEMBERS

1. When the investigator explained how to make a thickened liquid, did you understand the term 'nectar thick', 'honey thick' and 'pudding thick'? And why?

○ Yes.   ○ No.

(Why:____)

2. What is going to be your concern if you have to prepare thicken liquids for a family member?

____

____

3. When you have to make thickened liquids for your family member, do you think you will use the LST or you can make thickened liquid by your self?

4. Was the LST range understandable?

○ Yes.   ○ No.

Is there any reason for your answer? _________________________

5. Is the LST easy to operate?

○ Yes.   ○ No.

6. Any comments or recommendations?

____

APPENDIX D

NAÏVE ADULT-PARTICIPANT 1

LST data

Thickened Liquids		Trial 1				Trial 2				Trial 3			
		Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X
Orange Juice	3-3.9 cm (Nectar)	2.0 cm	2.12 cm	2.06 cm	X	2.3 cm	2.4 cm	2.35 cm	X	2.5 cm	2.6 cm	2.55 cm	X
	1.1-2.9 cm (honey)	0.9 cm	0.9 cm	0.9 cm	X	1.5 cm	1.56 cm	1.53 cm	O				
Water	3~3.9 cm (Nectar)	3.1 cm	3.7 cm	3.4 cm	O								
	1.1~2.9 cm (honey)	2.3 cm	2.5 cm	2.4 cm	O								
2% Milk	3~3.9 cm (Nectar)	2.8 cm	3.2 cm	3.0 cm	O								
	1.1~2.9 cm (honey)	2.1 cm	2.3 cm	2.2 cm	O								
Ensure	3~3.9 cm (Nectar)	2.7 cm	2.7 cm	2.7 cm	X	2.6 cm	2.8 cm	2.7 cm	X	2.6 cm	2.7 cm	2.65 cm	X
	1.1~2.9 cm (honey)	2.0 cm	2.3 cm	2.15 Cm	O								

APPENDIX E

NAÏVE ADULT-PARTICIPANT 2

LST data

Thickened Liquids		Trial 1				Trial 2				Trial 3			
		Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X
Orange Juice	3-3.9 cm (Nectar)	2.45 cm	2.38 cm	2.41 cm	X	2.56 cm	2.56 cm	2.56 cm	X	2.23 cm	2.0 cm	2.11 cm	X
	1.1-2.9 cm (honey)	1.45 cm	1.5 cm	1.47 Cm	O								
Water	3~3.9 cm (Nectar)	3.0 cm	3.4 cm	3.2 cm	O								
	1.1~2.9 cm (honey)	1.6 cm	1.58 cm	1.59 cm	O								
2% Milk	3~3.9 cm (Nectar)	1.5 cm	1.57 cm	1.53 cm	X	2.5 cm	2.4 cm	2.45 cm	X	2.6 cm	2.5 cm	2.55 cm	X
	1.1~2.9 cm (honey)	1.5 cm	1.45 cm	1.49 cm	O								
Ensure	3~3.9 cm (Nectar)	2.76 cm	2.7 cm	2.65 cm	X	2.8 cm	2.7 cm	2.75 cm	X	2.65 cm	2.65 cm	2.65 cm	X
	1.1~2.9 cm (honey)	2.3 cm	1.5 cm	1.9 Cm	O	cm	cm	cm		cm	cm	cm	

APPENDIX F

NAÏVE ADULT-PARTICIPANT 3

LST data

Thickened Liquids		Trial 1				Trial 2				Trial 3			
		Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X	Plate 1	Plate 2	Ave	O / X
Orange Juice	3-3.9 cm (Nectar)	2.32 cm	2.26 cm	2.29 cm	X	2.25 cm	2.35 cm	2.3 cm	X	2.4 cm	2.6 cm	2.5 cm	X
	1.1-2.9 cm (honey)	0.0 cm	0.0 cm	0.0 cm	X	0.0 cm	0.0 cm	0.0 cm	X	0.7 cm	076 cm	0.73 cm	X
Water	3~3.9 cm (Nectar)	2.43 cm	2.2 cm	2.31 cm	X	1.56 cm	1.72 cm	1.64 cm	X	1.71 cm	1.92 cm	1.81 cm	X
	1.1~2.9 cm (honey)	1.42 cm	1.54 cm	1.48 cm	O								
2% Milk	3~3.9 cm (Nectar)	2.76 cm	2.4 cm	2.58 cm	X	2.2 cm	2.3 cm	2.25 cm	X	1.97 cm	2.01 cm	1.99 cm	X
	1.1~2.9 cm (honey)	1.05 cm	1.15 cm	1.10 cm	O								
Ensure	3~3.9 cm (Nectar)	1.51 cm	1.57 cm	1.54 cm	X	1.87 cm	1.77 cm	1.82 cm	X	1.41 cm	1.63 cm	1.52 cm	X
	1.1~2.9 cm (honey)	1.91 cm	1.86 cm	1.88 cm	O								

APPENDIX G

QUESTIONNAIRE- PARTICIPANT 1

1. When the investigator explained how to make a thickened liquid, did you understand the term ‘nectar thick’, ‘honey thick’ and ‘pudding thick’? And why?

(X) ***Yes***. ○ No.

(Why: **N/A**)

2. What is going to be your concern if you have to prepare thicken liquids for a family member?

The consistency of the liquid after it settles for 2 minutes. Consistency changes after 2 minutes.

3. When you have to make thickened liquids for your family member, do you think you will use the LST or you can make thickened liquid by your self?

Use the LST

4. Was the LST range understandable?

(X) ***Yes***. ○ No.

Is there any reason for your answer? ***NA***

5. Is the LST easy to operate?

(X) ***Yes***. ○ No.

6. Any comments or recommendations?

Just time consuming for the LST

APPENDIX H

QUESTIONNAIRE- PARTICIPANT 2

1. When the investigator explained how to make a thickened liquid, did you understand the term ‘nectar thick’, ‘honey thick’ and ‘pudding thick’? And why?

(X) ***Yes***. ○ No.

(Why: **N/A**)

2. What is going to be your concern if you have to prepare thicken liquids for a family member?

Is it very important that the thickness would be exact, or is an approximation okay?

3. When you have to make thickened liquids for your family member, do you think you will use the LST or you can make thickened liquid by your self?

I would do it by sight.

4. Was the LST range understandable?

(X) ***Yes***. ○ No.

Is there any reason for your answer? ***NA***

5. Is the LST easy to operate?

(X) ***Yes***. ○ No.

6. Any comments or recommendations?

Since there is such a wide range of acceptable values in each category, I think I probably could guess fairly accurately.

Starting with the “honey” thickness made it more difficult to determine how much less to put in for the “nectar” thickness.

APPENDIX I

QUESTIONNAIRE- PARTICIPANT 3

1. When the investigator explained how to make a thickened liquid, did you understand the term ‘nectar thick’, ‘honey thick’ and ‘pudding thick’? And why?

(X) ***Yes***. ○ No.

(Why: **N/A**)

2. What is going to be your concern if you have to prepare thicken liquids for a family member?

Should I use this tool for every meal or drink?

3. When you have to make thickened liquids for your family member, do you think you will use the LST or you can make thickened liquid by your self?

Myself

4. Was the LST range understandable?

(X) ***Yes***. ○ No.

Is there any reason for your answer? ***NA***

5. Is the LST easy to operate?

(X) ***Yes***. ○ No.

6. Any comments or recommendations?

It is hard to modify the liquids. I think I keep make it so thick.

APPENDIX J

LST VALUES OF PURE DRINKS MEASURED IN THE MORNING AND AFTERNOON PERFORMED BY INVESTIGATOR

		Morning			Afternoon		
Liquids	**Plate**	Day 1 LST (cm)	Day 2 LST (cm)	Day 3 LST (cm)	Day 1 LST (cm)	Day 2 LST (cm)	Day 3 LST (cm)
	A-1	2.71	1.84	1.40	1.21	1.67	1.86
Water	A-2	2.20	2.14	1.72	1.82	1.90	1.88
	A-3	3.31	1.33	1.46	1.65	1.85	1.78
	A-4	2.82	2.18	2.13	1.87	1.70	1.55
	B-1	1.07	1.49	1.05	2.31	1.22	1.63
	B-2	1.48	1.08	1.06	0.87	1.33	1.02
Apple Juice	A-1	2.12	1.58	1.49	1.42	2.07	1.56
	A-2	1.79	2.32	1.52	2.15	1.82	1.70
	A-3	5.51	3.23	1.67	1.91	1.63	1.71
	A-4	2.00	1.98	2.27	2.09	1.90	1.41
	B-1	1.31	2.09	1.37	2.09	1.57	1.27
	B-2	1.19	1.27	1.36	1.51	1.38	1.37
Orange Juice	A-1	2.12	1.99	2.25	1.85	1.82	1.62
	A-2	3.30	2.27	1.80	1.95	1.76	1.61
	A-3	5.15	1.97	1.92	2.18	1.81	2.25
	A-4	2.62	2.02	1.58	1.93	2.95	1.68
	B-1	1.55	1.52	1.55	1.40	1.60	1.42
	B-2	1.43	1.56	1.37	1.46	1.63	1.40
2% milk	A-1	2.11	2.08	2.03	0.72	1.91	2.76
	A-2	2.08	4.01	2.03	2.98	2.23	2.47
	A-3	3.83	2.38	1.74	3.73	2.02	2.77
	A-4	3.52	3.73	2.27	2.18	1.69	1.98
	B-1	1.30	1.71	1.40	1.45	1.69	1.57
	B-2	1.65	1.90	1.43	1.63	1.85	1.46
Ensure	A-1	2.77	3.34	1.77	2.19	1.94	2.20
	A-2	2.85	2.50	1.87	2.51	2.31	1.74
	A-3	3.53	3.43	1.95	2.61	2.07	2.08
	A-4	3.11	3.25	2.10	2.80	2.03	1.82
	B-1	2.10	1.52	1.57	1.56	1.92	1.65
	B-2	1.68	1.53	1.61	1.64	2.01	1.51

APPENDIX K

LST VALUES (in cm) OF PURE DRINKS PERFORMED BY NAÏVE ADULTS

Liquids	Plate	Adult 1	Adult 2	Adult 3	Adult 4	Mean
	A-1	1.72	2.17	1.33	2.18	1.85
Water	A-2	1.66	3.98	1.91	2.61	2.54
	A-3	2.05	1.92	1.42	1.94	1.83
	A-4	3.15	2.28	2.13	2.40	2.49
	B-1	1.50	1.16	1.15	1.28	1.27
	B-2	1.60	1.03	1.12	0.99	1.19
Apple Juice	A-1	1.78	2.62	1.50	2.12	2.01
	A-2	1.81	2.50	2.15	1.74	2.05
	A-3	1.96	2.87	2.00	1.97	2.20
	A-4	1.83	1.77	2.35	1.86	1.95
	B-1	1.36	1.13	1.01	1.16	1.17
	B-2	1.37	1.13	1.12	1.31	1.23
Orange Juice	A-1	2.04	1.71	1.96	1.73	1.86
	A-2	2.06	2.35	1.90	2.51	2.21
	A-3	1.78	1.72	1.67	1.60	1.69
	A-4	1.87	2.21	2.05	2.31	2.11
	B-1	1.53	1.31	1.28	1.26	1.35
	B-2	1.50	1.29	1.25	1.21	1.31
2% milk	A-1	2.45	2.21	2.10	2.30	2.27
	A-2	2.02	2.03	1.92	2.01	2.00
	A-3	2.42	1.92	1.78	2.21	2.08
	A-4	1.39	2.02	2.27	2.40	2.02
	B-1	1.46	1.50	1.40	1.51	1.47
	B-2	1.47	1.56	1.46	1.38	1.47
Ensure	A-1	2.04	2.54	1.48	2.21	2.07
	A-2	2.06	2.93	1.89	1.88	2.19
	A-3	1.78	2.20	2.27	2.26	2.13
	A-4	1.87	2.34	2.10	1.80	2.03
	B-1	1.53	1.34	1.41	1.36	1.41
	B-2	1.50	1.40	1.43	1.30	1.41

APPENDIX L

LST VALUES (in cm) OF PURE DRINKS PERFORMED BY SLPs

Liquids	Plate	SLP 1	SLP 2	SLP 3	SLP 4	SLP 5	SLP 6	Mean
	A-1	2.84	2.32	3.06	2.21	0.50	2.60	2.26
Water	A-2	2.11	2.14	1.49	1.82	2.10	1.47	1.86
	A-3	2.10	2.33	1.98	2.37	2.58	1.66	2.17
	A-4	2.06	2.33	2.25	2.82	2.00	1.58	2.17
	B-1	1.46	1.20	0.94	1.25	1.10	0.77	1.12
	B-2	1.35	1.09	0.90	1.05	1.08	1.24	1.12
Apple Juice	A-1	2.50	2.00	1.99	1.70	1.88	1.46	1.92
	A-2	1.91	2.36	2.06	1.91	2.15	1.76	2.03
	A-3	2.16	1.91	1.69	2.02	1.77	1.44	1.83
	A-4	2.38	2.19	2.22	1.95	1.38	2.52	2.11
	B-1	0.97	1.25	1.12	1.07	1.18	1.11	1.12
	B-2	1.17	1.53	1.00	1.15	1.37	1.11	1.22
Orange Juice	A-1	2.32	2.28	2.06	2.28	2.38	1.50	2.14
	A-2	2.01	2.36	1.99	2.31	2.08	2.37	2.19
	A-3	2.07	2.21	1.36	2.59	2.06	1.80	2.02
	A-4	1.95	2.24	2.22	2.15	1.78	1.75	2.02
	B-1	1.31	1.52	2.51	1.32	4.25	1.34	2.04
	B-2	1.48	1.38	1.16	1.42	1.38	1.30	1.35
	A-1	2.23	2.75	2.85	2.62	2.90	1.77	2.67
2% milk	A-2	2.98	2.06	2.40	3.74	2.70	2.80	2.78
	A-3	2.56	2.15	3.18	1.88	2.51	1.60	2.46
	A-4	3.03	2.55	2.82	2.78	1.97	2.00	2.63
	B-1	1.41	1.21	1.43	1.38	1.51	1.41	1.39
	B-2	1.35	1.18	1.46	1.41	1.74	1.66	1.43
	A-1	2.80	2.33	2.46	2.78	2.69	3.16	2.70
Ensure	A-2	2.23	2.50	2.02	2.32	2.42	2.06	2.26
	A-3	2.18	2.01	1.71	2.72	2.52	1.22	2.06
	A-4	2.38	2.74	2.33	2.26	4.07	1.91	2.62
	B-1	1.48	1.60	1.19	1.62	1.66	1.60	1.53
	B-2	1.40	1.46	1.50	1.50	1.56	1.52	1.49