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The eating capability: constituents and assessments

Laura Laguna[1] and Jianshe Chen[2,*]

1. School of Food Science and Nutrition, University of Leeds, Leeds LS2 9JT, UK

2. School of Food Science and Biotechnology, Zhejiang Gongshang University,
Hangzhou, Zhejiang 310018, China

* Corresponding author

Tel: (00)86 571 28008904

Fax: (00)86 571 28008900

Email: jschen@zjgsu.edu.cn

Abstract

With the rapid growth of elderly populations, the food industry is under increasing pressure to provide texture-modified food for safe consumption by these vulnerable populations. The imminent technical challenges to the manufacturing of food for elderly consumption are the lack of knowledge of the elderly's physiological capability to eat and swallow and, particularly, the lack of technical guidance in matching texture properties with the individual's capability of eating. This review proposes the term "Eating Capability" to represent the individual's abilities for food consumption. This term collectively includes the following four groups of quantifiable parameters: food handling capability (e.g., hand gripping, finger gripping, and coordination), oral manipulation capability (e.g., lips sealing, biting and mastication, tongue pressing, and swallowing), oral sensing capability (e.g., tasting and texture discrimination), and cognitive capability (e.g., information seeking and processing, opinion forming, and decision making). According to this definition, various capacities related to eating performance and, particularly, the implications of any impairment in such capability are discussed in detail in this paper; we pay particular attention to vulnerable elderly consumers. Another primary objective of the review is to introduce feasible techniques and methods that are currently available for quantitative assessment of these parameters. With the growing research activities in food for elderly, we hope that this review will stimulate new thinking and help the food industry to establish novel techniques to design and manufacture quality food for safe consumption by elderly people.

Keywords: eating capability, food oral processing, texture modification, mastication, swallowing

Highlights

The frail population could not properly perform eating actions and are at risk of malnutrition.

The assessment of the eating actions has namely “eating capability” and has been explored in the following four domains: hand, oral, mental and sense capability.

A number of techniques and methodologies have been discussed for their use as reliable assessments of the eating capability components.

1. **Introduction**

It is common knowledge that ageing will cause inevitable weakening of one’s physical, physiological, and mental capability. This weakening is also true for eating and oral food consumption in many elderly people. An immediate effect of eating difficulty is reduced food intake, an increased risk of malnutrition and, possibly, more infections among elderly people (McLaren & Dickerson, 2000; Ono, Hori, Tamine, & Maeda, 2009), as well as a compromised quality of life. For these vulnerable consumers, texture modified diets are required to ensure safe consumption.

To date, eating difficulties have mostly been studied from the perspective of personal care, especially in nursing interventions with elderly (Westergren, Unosson, Ohlsson, Lorefält, & Hallberg, 2002) and in the stroke population (Jacobsson, 2000). For example, Westergren et al. (2002) studied eating difficulty among elderly living at home and in the hospital by observing individuals’ eating habits during a regular meal. These researchers observed difficulties, such as in sitting, manipulating food on the plate, transporting food to the mouth, opening and closing the mouth, and swallowing, and found a close association of a high level of eating difficult with low energy intake and malnutrition. In a separate study, Jacobsson (2000) drew similar conclusions after studying the eating behaviour in people affected by stroke as well as in healthy elderly people The author also video-recorded subjects consuming test-meals with different consistencies (thin liquids, thick liquids, jelly drinks, banana and crisp bread) and analysed their eating performance. The proper identification of difficulty in eating actions helped both the carer and patient develop an appropriate rehabilitation strategy.

However, Jacobsson (2000) noted the lack of reliable instruments for eating assessments. Assessments of an eating processing and the capability of food oral consumption have thus far largely been experience-based and subjective. Assessments were qualitative and easily influenced by the observer (Jacobsson, 2000). Outcomes from such assessments were not often comparable between different studies. Therefore, it is desirable to establish easily quantifiable parameters and methods for objectively assessing these parameters. For this reason, the authors of this paper propose “Eating Capability” as a collective term to represent an individual’s capability of oral food consumption. Based on the fact that eating involves a series of food–body interactions, the term eating capability should be a combination of one’s physical, physiological, and mental-coordination capabilities in handling and consuming food. This paper will explain the physical and physiological meaning of these capabilities and important implications if one such skill is impaired. The main focus of discussion is on the feasible methods for quantitative assessment of these capabilities. Our long-term aim is to establish possible correlations between one’s eating capability and the textural properties of food to ensure safe food consumption by vulnerable elderly consumers.

2. Constituents of the Eating Capability

During the eating process, one has to perform a sequence of coordinated actions. Before food ingestion, the following actions must occur: manipulating food on the plate with hands or cutlery, lifting up food for ingestion, jaw lowering for mouth opening and more. After food is ingested in the oral cavity, the following are performed either sequentially or simultaneously: jaw lifting and mouth closing, biting, mastication, transporting, mixing, sensory detecting, saliva secretion, bolus formation, swallowing, and more. All of these actions also involve opinion formation and decision-making. To execute all of these actions, some specific capabilities (physical, physiological and mental) are needed for execution and precision.

The associated capabilities needed for an eating process can probably be grouped into the following four categories: the hand manipulation capability, oral manipulation capability, sensation capability, cognition (mental) and coordination capability. All of these capabilities can be collectively termed as the Eating Capability, as shown in Figure 1. Each category of the eating capability can further be characterised by some associated measureable parameters. The meanings and implications of capability impairment will be discussed in detail in the following sections.

2.1 Hand manipulation capability

The hands are the most versatile parts of the human body, and they are essential tools for all sorts of situations in our daily life. Any injuries, diseases, or distortions of the hand can affect our quality of life (Olandersson et al., 2005). In relation to eating, the hand manipulating capability is important both before and during the course of a meal (food preparation and hand cutlery manipulation). This capability can be defined as the ability of an individual to exert an appropriate force, in a coordinated manner, to manipulate food from package opening until it reaches the mouth. In relation to self-feeding, the following four types of actions require hand manipulation: food package handling and opening; managing food on the plate (e.g., cutlery or butter spreading); handling and lifting an object (e.g., a glass of water); and transporting food from the plate to the mouth.

Regarding food preparation, many elderly consumers experience some difficulties in opening certain types of packaging. Winder, Ridgway, Nelson, and Baldwin (2002) also noted that difficulty in dealing with food packaging is the main barrier for elderly consumers in food consumption, and it is often a cause of packaging-related accidents. This phenomenon has been evidenced by a number of reported accidents in which inappropriate tools were used in the opening process (Lewis, Menardi, Yoxall, & Langley, 2007).

The action of grasping and lifting food objects from the plate to the mouth is directed by a complex interplay between multiple sensorimotor systems to signal, analyse and process the mechanical interactions and constraints between the body and object (Nowak & Hermsdörfer, 2003). To overcome problems in hand manipulation, a range of adaptive eating utensils has been developed. Examples include a nosey cup to avoid bending the neck in case of dysphagia, cutleries for people with grasping difficulties, plate guards to avoid spillage in people with low vision, and a weighted mug for those with tremor problems. Although these tools are very helpful, they only address a part of the eating difficulties. For example, patients with Parkinson’s disease have trembling hands and difficulty co-ordinating cutlery on the plate and transporting food to the mouth (Andersson & Sidenvall, 2001); also, those individuals who suffer from skeletal muscle weakness (due to the ageing or pathology) have reported problems in the hand grip precision and force (Kurillo, Zupan, & Bajd, 2004).

2.2 The oral processing capability

The oral cavity is the first part of the digestive tract and is bounded anteriorly by the upper and lower lips (vermilion surface, mucosal lip, and labial mucosa), laterally by the cheeks, superiorly by the hard palate and inferiorly by the tongue and muscles attached to the internal side of the mandible (Pereira, 2012). Food oral processing is conducted in a highly coordinated manner (coordinated actions of orofacial muscles, lips, cheeks, teeth, tongue, and palate) and is under close control by the central nervous system, which generates efficient masticatory movements (Koshino, Hirai, Ishijima, & Ikeda, 1997). The main functional purposes of the process are to transform non-swallowable food into a swallow-able bolus and to transport it smoothly from the oral cavity into the stomach. The process includes all oral actions from the first bite up to following swallowing (details are shown in Figure 2).

2.2.1 Actions in the oral cavity: biting, mastication and swallowing

2.2.1.1 Biting

The first bite (of a solid or semi-solid food) is conducted by forcible occlusion of the opposing edges of the upper and lower incisors (Okada, Honma, Nomura, & Yamada, 2007). Although that it is a single event, the first bite can give abundant sensory feedback about the textural features of the food, including the hardness, springiness and cohesiveness, among others (Chen, 2009). During the bite, the pressure exertion on teeth causes slight stretching of the periodontal ligaments, sending information to the central nervous system for texture interpretation. The periodontal ligaments are able to detect very small forces (1 N or lower) (Lucas, Prinz, Agrawal, & Bruce, 2004).

How first bite is conducted by an individual depends on a number of factors, such as the physical properties of the food and subjects' physiological conditions. The maximum biting force one can exert is affected by several factors such as the dentition status and the jaw-closing muscle strength (Tortopidis, Lyons, Baxendale, & Gilmour, 1998), face morphology (i.e. adults with normal facial morphology have higher biting force than long-faced adults) (Proffit, Fields, & Nixon, 1983), gender (males can apply generally larger force than females), ethnicity (e.g. Eskimos are able to apply higher biting force than white American) (Bourne & Szczesniak, 2003) and age (aging will have reduced biting strength) (van der Bilt, 2012). The maximum biting force ranging between 60N (Fontijn-Tekamp et al., 2000) and 700 N (Ferrario, Sforza, Serrao, Dellavia, & Tartaglia, 2004) have been reported.

2.2.1.2 Mastication

The purpose of mastication is to reduce food into smaller particles that are suitable for swallowing, with the help of saliva and, in some cases, the liquid released from the food, resulting in the formation of a cohesive mixture (the bolus) (Jalabert-Malbos, Mishellany-Dutour, Woda, & Peyron, 2007). The mastication process is a succession of chewing cycles (Woda, Foster, Mishellany, & Peyron, 2006). Each cycle consists of one jaw-opening, followed by one jaw-closing, movement, which is the rhythm generated by a brain stem central pattern generator (Woda et al., 2006).

The possible consequences of impaired mastication capability vary and depend on its causes. If this impairment is caused by tooth loss, individuals will generally have changed eating habits and often prefer easy-to-chew or over-cooked food. Large food particles may be swallowed, increasing the risk of choking for these individuals. If reduced masticatory capability is tongue-related, individuals will have great difficulty moving food within the oral cavity. The oral preparation phase for bolus swallowing will be compromised. If the problem is due to inadequate secretion of saliva, bolus formation will be difficult and a much longer oral processing time will be needed.

Mastication and dentition

One's masticatory capability includes the ability to grind or pulverize a chewable food (de Liz Pocztaruk et al., 2011; Hatch, Shinkai, Sakai, Rugh, & Paunovich, 2001). Physiologically, individuals have a large variation in their mastication behaviour (e.g., number of cycles, muscular activity, duration, or lateral and vertical mandible movement) and can be grouped according to their masticating characteristics. The most obvious grouping is by gender, as has been reported by Woda et al. (Woda et al., 2006), who assessed electromyography (EMG) activities of chewing muscles and observed significantly higher masticatory frequency in males than in females.

Masticatory efficiency decreases for subjects who have missing teeth (Fontijn-Tekamp et al., 2000; Miyaura, Morita, Matsuka, Yamashita, & Watanabe, 2000). The contact area between the upper and lower teeth is important for oral food breakdown. Replacing missing teeth with dentures can improve mastication, but it cannot always fully recover the efficiency of natural teeth (N'Gom & Woda, 2002). People who have lost post canine teeth, and replaced them with removable dentures (Fontijn-Tekamp et al., 2000; Kapur & Soman, 2006; Pocztaruk, Frasca, Rivaldo, Fernandes, & Gavião, 2008), have a significantly reduced masticatory function. For this reason, elderly people who usually suffer from more tooth loss often have partially depleted mastication capability.

Generally speaking, subjects with incomplete dentition swallow relatively larger food particles even if they try to compensate for tooth loss with an increased number of chewing cycles and longer duration of mastication (Woda et al., 2006). Bates, Stafford, and Harrison (1976) observed that dentures can be loose and moveable during eating. In such a case, the tongue has to be used to stabilize and aid the retention of dentures. This means that dentition not only has a decreased efficiency of oral food breakdown, the tongue's capability in positioning food could also be compromised.

The dentition status will also influence an individual's food choice. Rana et al. (Ranta, Tuominen, Paunio, & Seppänen, 1988) observed that when the dentition status is low (i.e., wearing complete dentures), the intake of difficult-to-chew food items (e.g., roots, vegetables, fruits and meat) becomes less pleasing for denture wearers. Furthermore, subjects with a reduced masticatory efficiency will often require extra work in food preparation. For example, some fruits and vegetables need to have their skins removed and some foods need to be overcooked to facilitate their mastication deficiency (Walls & Steele, 2004). Table 1 summarizes the main problems that denture wearers suffer compared to those with natural teeth.

Mastication and the role of saliva

Saliva is a biological fluid that is naturally secreted from inside the human mouth and required for eating and oral health (Pedersen, Bardow, Jensen, & Nauntofte, 2002). Saliva plays an important role in bolus formation by mixing with food particles to form a coherent and smooth bolus (Prinz & Lucas, 1997). The enzymes (i.e., α-amylase and lipase) in saliva are very active ingredients (i.e., starch and lipids) that attack some food components and cause immediate structural breakdown and viscosity decrease. Furthermore, saliva also plays an important role in sensory perception by functioning as a reservoir, which holds food ingredients for a continuous flavour release (Doyennette et al., 2011).

In addition to eating-related functions, saliva secretion ensures continuous rinsing of the mouth and helps to clean the oral cavity against harmful pathogens. Lubrication and protection of the oro-oesophageal mucosa is another important function of saliva (Pedersen et al., 2002). The mucins present in saliva create a slippery effect so that a food bolus can easily slide through the oesophagus (Pedersen et al., 2002). This finding is perceived as critically important for safe swallowing (Engelen, Fontijn-Tekamp, & Bilt, 2005).

Many health conditions could influence salivary secretion; in particular, many medications cause diminished salivary secretion, a phenomenon that is clinically called xerostomia (dryness in the mouth) (Walls & Steele, 2004). Subjects with xerostomia will not only have problems with food chewing and swallowing, they will also have problems with taste, speech, and tolerance of dentures (Narhi et al., 1992). The causes of reduced saliva secretion can be either pathology-related or non-pathology-related.

Pedersen et al. (2002) reported cases of gland dysfunctions as a result of chronic inflammatory autoimmune disease, endocrine diseases, neurological disorders, genetic disorders, undernourishment, infections and other conditions, such as hypertension or fibromyalgia, among others. Some medications/treatments (e.g., radiotherapy, antidepressants or chemotherapy) can cause a significant loss of saliva secretion (Pedersen et al., 2002). Some non-pathological statuses may also affect the saliva secretion and composition. Budtz-Jogersen et al. (Budtz-Jørgensen, Chung, & Rapin, 2001) reported that healthy elderly individuals often suffer salivary gland dysfunction and xerostomia. The situation is worsened by the fact that many elderly may suffer from other illnesses and be on regular medications.

Mastication and the tongue

The tongue is a mass of mobile muscle inside the oral cavity. Proper functioning of the tongue is critically crucial for both eating and speaking. During oral food processing, the tongue acts as a mechanical device for food manipulation and transportation (Heath, 2002) as well as the dominant source of energy to initiate bolus flow (Alsanei & Chen, 2014). Chemoreceptors and mechanoreceptors on the tongue surface act as the most delicate sensation systems for detecting and discriminating the taste and textural properties of food (Hiiemae & Palmer, 1999). The tongue (Hiiemae & Palmer, 1999) also helps to move food distally through the oral cavity, from the anterior to the pharynx (Pereira, 2012). Without a doubt, any dysfunction of the tongue (i.e., lack of coordination or motor disorder) will provoke difficulties in eating and swallowing (Ueda, Yamada, Toyosato, Nomura, & Saitho, 2004).

2.2.1.3 Bolus swallowing

Bolus swallowing is a transportation process that moves food from the oral cavity to the stomach via the oral-pharyngeal-oesophagus tract. The entire process takes a few seconds from the initiation to completion (Dodds, 1989). The swift switch between breathing and swallowing is vital (Matsuo & Palmer, 2008). This is achieved by physical closure of the airway from elevation of the soft palate (to seal off the nasal cavity) and titling of the epiglottis (to seal off the larynx) as well as the neural suppression of respiration in the brainstem (Nishino & Hiraga, 1991).

Dysphagia is the term that is often used to refer to those who have swallowing disorders (Hori et al., 2009), and it affects to a range of populations, including the elderly, dysphagia patients, cancer patients, and more. The exact effect of ageing on oropharyngeal swallowing is not yet fully understood and requires collaboration between oral physiologists, food scientists, and clinical researchers (Logemann, 2007). The other collective group that is affected by swallowing disorders includes patients who have a cerebrovascular accident or neurologic disorders. In addition to the above causes, dysphagia symptoms can also be related to head and neck cancer (Langmore, 2003) (Gaziano, 2001) or Parkinson’s disease (Palmer, Drennan, & Baba, 2000) because of the general abnormalities in muscular movement (Troche, Sapienza, & Rosenbek, 2008).

The major risks of inappropriate bolus swallowing are aspiration and choking. The former is caused by accidental entering of food residues into the larynx pipe and will cause a serious cough or even infection if oral bacteria also enter. The latter is caused by the blocking of the airway by large food particles in the pharyngeal region and could cause a fatal consequence (suffocation). Therefore, the capability of bolus swallowing refers to two important aspects, the capability of muscle coordination for swift switch between the breathing and swallowing actions and the strength of swallowing muscle contraction to create a sufficiently high (oral) pressure to move the bolus forward.

2.3 Sensing capability

Sensing capability is the ability of an individual to evaluate and perceive sensory stimuli of food through the five human senses (sight, smell, taste, touch and hearing).

During eating, people enjoy and appreciate food via some specific sensory attributes, including the appearance, odour/aroma/fragrance, consistency, texture and flavour (aromatics, chemical feelings and taste) (Meilgaard, Carr, & Civille, 2006).

When the sensing capability for these sensory attributes is hampered by a physiological factor (e.g., ageing), pathological state (e.g., stroke), or pathological treatment (e.g., chemotherapy cancer treatment), the losses and distortions of the sensing perception can greatly compromise our enjoyment of eating as well as the appetite and overall food intake. Some well recognized effects of sense impairment on the eating process are summarized in Table 2.

2.3.1 Vision

Using the sense of vision, humans determine where an object is in 3-dimensional space as well as its appearance (colour, shape, size, etc). In many cases, the first sensory contact with food is through the eyes (Wadhera & Capaldi-Phillips, 2014). Therefore, the capacity for sight is important to eating for two reasons, the sensory-motor (ability required for reaching the food) and the sensory-satisfaction (visual pleasure of the food).

With respect to the sensory motors abilities, Muurinen et al. (Muurinen et al., 2014) showed that vision impairment affects the nutritional status due to the difficulties in shopping, preparing and having meals. Crews and Campbell (Crews & Campbell, 2004) found that old people with vision impairment reported more difficulty in preparing meals than people with other sensory problems (19.2 % vs. 6.3 %). It was also found that vision impairment was frequently associated with malnutrition (Muurinen et al., 2014) or a low body mass index (BMI) (Steinman & Vasunilashorn, 2011).

It has to be said that before a food is consumed, its appearance provides expectations about the other sensory attributes (taste, flavour, palatability, etc) influencing food acceptance and consumption (Hurling & Shepherd, 2003). Previous authors have indicated that vision affects the taste quality and hedonic rating of food items (van Beilen et al., 2011; Verhagen & Engelen, 2006), affecting odour perception (Engen, 1972) and, consequently, appetite (or the motive that makes a person seek food) (De Graaf, Blom, Smeets, Stafleu, & Hendriks, 2004).

2.3.2 Smell

The olfactory system is responsible for sensing and detecting the entire spectrum of food aroma, through either sniffing or during mastication when volatile compounds stimulate via the retro nasal system (Popper, 2003). The olfactory epithelium has been shown to be sensitive to trauma, disease and aging. Olfactory receptors could also be targets of several viral agents (Stroop 1995). Dysfunction on the olfactory system is called hyposmia and a complete loss of the ability to smell is called anosmia (Havermans, Hermanns, & Jansen, 2010).

Havermans et al. (2010) affirmed that the hedonic evaluation of the food rested on its flavour (taste and smell). If one is unable to perceive food aromas, the flavour diminishes. Duffy et al. (Duffy, Backstrand, & Ferris, 1995) studied how the olfactory dysfunction affects daily living and observed that elderly individuals with olfactory dysfunction had lower interest in food-related activities (e.g., cooking) and lower preference for many nutritious food (e.g., sour/bitter taste as citrus fruits), but they had a higher intake of sweets and fat. Surprisingly, many elderly were not aware of the loss of olfactory capability (Popper, 2003), which was probably because the loss of this capability is often gradual and occurs over a period of many years (Rolls, 1993).

Trigeminal sense is another important sensing mechanism that is linked to olfactory receptors. Some chemical irritants (e.g., ammonia, chilli peppers, and menthol) can stimulate the trigeminal nerve ends (Meilgaard et al., 2006). The trigeminal nerve innervates the nasal passageways. It is linked to olfactory receptors, but it is separated from the olfactory nerve. It has been reported that anosmics have an increased threshold of trigeminal substances, which can hamper sensory enjoyment (Van Toller, 1999).

2.3.3 Taste

Taste is a gustatory function that is defined as a chemical stimulation to taste receptors in the oral cavity. The following five primary tastes have been identified: sweet, sour, salty, bitter and umami and, in food applications, the combination of these basic tastes forms various complex tastes (Brondel, Jacquin, Meillon, & Pénicaud, 2013). Taste alteration occurs often among elderly populations, but physicians frequently overlook its negative implications to health. One well-known fact is that taste alteration can aggravate the anorexic states and contribute to malnutrition (Brondel et al., 2013). Compared with younger individuals, the elderly have greater difficulty detecting the presence of sweet, sour, salty or bitter as well as umami (Schiffman & Graham, 2000). For many elderly people, taste problems are also associated with cancer and cancer treatment (Ravasco, 2005), diabetes, renal and liver conditions, arthritis, Alzheimer's disease, cognitive impairment, and the use of certain medications (Boltong & Campbell, 2013).

Both smell and taste are sensory features via chemosensory mechanisms. The two sensory features are closely linked and are influenced by each other. In particular, a change in the olfactory capability can significantly affect how a food tastes (Ravasco, 2005). Such cases are usually treated as chemosensory disorders, which are linked to the decrease of food acceptability (Mattes et al., 1990). Hutton, Baracos, and Wismer (2007) found that weight loss is a common finding among individuals who are suffering from altered taste and smell perception.

Taste alteration can be classified into the following three different categories according to Schiffman and Graham (Schiffman & Graham, 2000): totally absent (ageusia), reduced capability (hypogeusia) and distorted capability (dysgeusia). This grading is rather qualitative in assessing the individuals' sensing capability. A more quantitative assessment can be made based on the threshold determination for either detecting or discriminating some particular tastes.

2.3.4 Touch

The sense of touch can be divided into two different categories (Meilgaard et al., 2006), somesthesis (tactile, skin feel) and kinesthesis (deep pressure). The former refers to the touching senses felt through the surface nerves responsible for the sensation of touching pressure, heat, cold, itching and tickling, while the latter is felt through nerve fibres in the tendons, muscles and joints.

Both somesthesis sensing and kinesthesis sensing contribute to our texture sensation. Once the food is inside the oral cavity, the texture will be perceived by numerous mechanoreceptors as well as thermoreceptors located underneath oral surfaces. The tongue, periodontal ligament and tissues lining of the oral cavity provide kinesthesic information from the oral musculature (Essick & Trulsson, 2009). Previous studies have reported that individuals wearing whole or partial removable dentures have a lower enjoyment of the food texture, which is probably from the reduced tactile information from the mouth (Popper, 2003).

A very recent study conducted in the authors' group revealed a huge variation in the touching sensitivity among human populations (Laguna et al., 2015). A comparison between the elderly population and young population showed a substantial difference, wherein elderly people had a much higher threshold of tactile detection. The effects of weakened touching sensitivity on an individual's health and well-being have not been fully explored. However, some early evidence has shown that the consequences could be serious. Smith et al. (Smith et al., 2006) reported that children with poorly functioning tactile systems may have difficulty enjoying the texture of solid food.

2.3.5. Proprioception

Proprioception is defined as “the perception of body position and movements in three dimensional space”. The overall proprioceptive performance of an individual is determined by the quality of both the available proprioceptive information and an individual’s proprioceptive ability (Han, Waddington, Adams, Anson, & Liu, 2015).

During eating, one needs to reach for food and bring it to the mouth. This “reach-to-eat” action is guided by two different mechanisms, vision and proprioception (de Bruin, Sacrey, Brown, Doan, & Whishaw, 2008). Visual impairment has led to great difficulties for many elderly in food handling (section 2.3.1), and the loss of proprioception sense is an added difficulty to the feeding action (Gordon, Ghilardi, & Ghez, 1995).

2.3.6 Hearing

Hearing is another very important source of sensory perception. We do hear eating, especially for crispy and crunchy food. Many authors have reported that the sound and acoustic characteristics of a food product can influence the consumers’ appreciation and enjoyment of the food (Luyten, Plijter, & Van Vliet, 2004). Hearing impairment may negatively affect one’s eating experience and pleasure. However, people with hearing impairment are still capable of appreciating crisp food. It is believed that internal (skull) vibration could play an equally important role to that of external acoustic transmission for sensing and appreciating crisp food (Van Der Bilt, de Liz Pocztaruk, & Abbink, 2010).

2.4 Mental and coordination capability

The mental and coordination capability refers to the ability of an individual to make a series of decisions in relation to feeding and being able (from a motor point of view) to coordinate different tasks involved in an eating process. This requires appropriate mental power and capability for information intake, information processing, opinion forming, decision making, and action coordination. In relation to eating, one must be able to make decisions, such as what to eat, how frequent, the quantity of intake, and others. One should also be able to coordinate various actions linked to somatic conditions or actions to perform the eating process.

2.4.1. Mental capability for eating decisions

Dovey (2010) explained that around the mealtime, there are many cognitive scripts. The decision making on the type and quantity of food is based on a complex interplay between biological, sensory, environment and learned influences. For healthy individuals, the well-functioning appetite forms part of a feedback circuit that influences the pattern of eating at the following three levels: first, the psychological; second, the peripheral physiological and metabolic events; and finally, the neurotransmitter and metabolic interactions in the brain. When the appetite system does not operate harmoniously, numerous problems appear. The disruption of this equilibrium could result in obesity or eating disorders, such as bingeing or vomiting.

There are clear indications that eating disorders is a frequent problem for people with intellectual disability (Hove, 2004). For example, Rimmer and Yamaki (Rimmer & Yamaki, 2006) noted that obesity is a major health threat in persons with intellectual disability and that impaired cognitive capability diminishes both one's capability of sensory perception and the control of food intake. The prevalence of obesity in adults with intellectual and developmental disabilities is approximately two to three times greater than that in the general population (Rimmer, Braddock, & Marks, 1995; Rimmer & Wang, 2005).

In children with intellectual developmental deficits (sub-average in cognitive status), different eating and feeding problems have also been reported. The problems include mealtime tantrums, bizarre food habits, multiple food dislikes, selectivity by food textures, delay or difficulty in chewing, sucking, delay in self-feeding, pica (ingestion of non-eatable substances), overeating or under-eating, and rumination (Linscheid 1983). Gal, Hardal-Nasser, and Engel-Yeger (2011) also linked eating problems with the intellectual developmental deficit (IDD)level. The authors found problems of malnutrition across all groups with different levels of IDD.

2.4.2. Mental capability and the coordination capability of eating actions

Eating is a complex sensorimotor process that involves integration between the functioning muscles and nervous system. For example, mastication involves coordinated activities of the teeth, jaw muscles, temporomandibular joints, tongue and other structures, such as the lips, palate and salivary glands. Similarly, a swallowing action requires a complex coordination between breathing and bolus pushing. It remains a myth how humans develop such skills since birth. Wolf (1992) studied the eating (sucking) behaviour of new born babies. They demonstrated that milk sucking requires a good coordination of breathing, sucking and swallowing, and involves functional interactions between the jaw, tongue, soft palate, pharynx, larynx and oesophagus. Brown and Ross (2011) further added that sensation coordination is also an essential part of milk sucking. Infants must sense and react to tactile, kinaesthetic, proprioceptive, olfactory, auditory and visual inputs to coordinate sucking, swallowing and breathing.

Summerset al. (2008) also studied the activities of daily living in children who are 5 to 9 years old with developmental coordination disorder (deficit in motor skills). Through focus group discussion and interviewing the parents, they investigated the eating behaviour of these children, among other daily activities, such as dressing or oral hygiene. They found that these children had difficulty with cutlery manipulation and were slow in eating. Additionally, these children were often described as messy eaters.

In a separate study on children eating, Hung et al. (2012) observed reach-grasp-eat tasks by children with cognitive problem and noted difficulty in the coordination between their body parts. The researchers studied their movements to grab a biscuit (cookie) and transport it to the mouth and observed that inappropriate rotation of the head and wrist resulted in difficulty with the eating process.

Difficulties in end-point locations have also been observed in adults after strokes. Malnutrition in stroke patients (Paquereau, Allart, Romon, & Rousseaux, 2014) is common and caused by eating problems, such as inadequate lip closure, mastication, dysphagia, and loss of sitting balance (McLaren & Dickerson, 2000), as well as other difficulties, such as manipulating food on the plate or transporting food to the mouth (Jacobsson, Axelsson, Wenngren, & Norberg, 1996). In the elderly population, stroke is one of the major causes of functional disabilities and multiple researchers have reported on its effects on eating in these people (McLaren et al. 2000, Jacobsson et al. 2000)

3. Assessments of the Eating Capability

3.1 Hand manipulation capability

The ability to manipulate food by hand involves two dimensions, an adequate force to perform the movement (i.e., to lift a glass) and a degree of coordination to execute the movement. These two dimensions are related and affect each other. For example, to open an “easy to open” package, one has to first have sufficient hand dexterity (or coordination) to initiate the peel force and second have enough force to tear the plastic apart.

The capability of an individual in applying hand holding/gripping can be precisely measured by various techniques. A hand dynamometer has been reported to be easy to use for such a purpose (Sasaki, Kasagi, Yamada, & Fujita, 2007) (Figure 3). However, the maximal voluntary grip force only reflects partial information of hand movement and does not give information about the dynamics of the force application. To obtain additional knowledge on the sensory-motor control, Hermsdorfer et al. (2003) developed a method for dynamic holding and transporting different spherical objects, allowing for analysis of the impairments of manipulative gripping control in patients with a chronic cerebral stroke. Additionally Kurillo et al. (2004) used the load curves, adding different end-objects of different shapes (nippers, pinch, spherical, lateral and cylindrical grip, see Figure 3), so that they could monitor the functionality of different hand muscles. This last device is more versatile and capable of providing different types of gripping forces that are used in daily activities. The values obtained from such measurements can give an effective indication of the strength and coordination of the hand (as well as finger) muscles and, therefore, the capability of food handling.

The core concern of the hand manipulation capability assessment is the prediction of user’s confidence and the food and food package design. Marks et al. (2012) investigated food package designs for elderly use and found that the current package design were not fit for purpose. They reported that 82 % elderly found jam jars difficult to open, 78 % mentioned difficulty with peel-able meat/cheese packages, 69 % mentioned difficulty with bottles, 68 % mentioned difficulty with peel-able coffee containers, and 62 % mentioned difficulty with peel-able cereal packs. By measuring the maximum hand gripping capability of elderly women, Lewis et al. (2007) suggested that, for safe use by elderly women, the maximum opening torque for a bottle/jar design should be no larger than 2 Nm.

Considering that the hand manipulation capability consists of two very different aspects (the maximum magnitude of the gripping force and coordination of muscle activities), authors tend to propose assessing this capability assessed in the following two steps. First, use a hand dynamometer for general strength measurement of hand holding and gripping. Second, use the finger gripping force to assess fine coordination. The finger gripping force requires fine control of many minor hand muscles. This measurement can be performed with some of the methodologies proposed by Marks et al. (2012) and Kurillo (2004) or using the same gripping sensor for biting force measurements (see section 3.2.1.2).

3.2 Oral capability

3.2.1 Capability of oral force creation

The oral cavity is the core focus of an eating process. Food conversion and sensory perception all happens in this place. Food is chewed, moved, mixed, and squeezed inside the mouth via a combination of various oral actions, involving the lips, teeth, tongue, and other orofacial muscles. The capability of performing each action will affect one’s overall capability of eating and oral food processing.

3.2.1.1 Lip closing force

Lip closing is a very important oral function that helps to keep food inside the mouth and prevents oral fluid escape. Proper lip sealing is even more critical during swallowing when an elevated pressure is created inside the oral cavity. The capability of lip sealing can be measured by the magnitude of the closing force by the two lips, as has been reported in clinical studies of patients after cleft lip surgery (Trotman, Barlow, & Faraway, 2007) and orthognathic surgery (Umemori, Sugawara, Kawauchi, & Mitani, 1996). In earlier works, a dynamometer with dial gauges, manometer system, and load cell with strain gauges have been used as pressure sensors to measure the lip force against a certain point on the surface of the teeth. Many other rather simpler but reliable methods have also been reported and examples are listed in Table 3.

The pressure distribution between closed lips can also be determined using a device developed by Umemori et al. (1996). This device consists of the following three parts: sensor cartridge, light source and connector, and it is capable of displaying images of lips pressure-distribution. A much simpler version was developed later, which consists of a sensor, lip adaptor and digital display. Ueki et al. (2012) used Lip de Cum (R) with a lip holder (Ducklings (R)) for lip strength measurements. The device contains four strain gauges. The subject closes his or her upper and lower lips without teeth touching the device and detected signals are converted into a load value (N). Trotman et al. (2007) designed a device where a load-sensitive cantilever with an integrated lip saddle is mounted to an interdental yoke. First, the upper lip strength was measured. Then, the lower lip force was measured as the interdental yoke reached the lower mandible. The main benefit of the technique is that it not only registers the maximum force, it also registers the reaction time, rising time, peak force and target force (Table 3).

Different tools have been used to measure the maximum pressure and time to reach the maximum (Ueki et al. 2012 and Trotman et al. 2007). A combination of both parameters could possibly give useful information about the roles of the lips during the entire eating process. Although lip closing has been recognized as an important factor that interferes with food oral processing and swallowing, very limited research has been reported in literature, particularly for cases of elderly people.

3.2.1.2 Biting force

The biting force is an important variable that determines the functional state of the masticatory system (Van Der Bilt, Tekamp, Van Der Glas, & Abbink, 2008). However, although many studies have been reported in literature in this regard, there is no standard procedure. More confusing is the large variation of the biting forces recorded in different studies. For example, Fontijn-Tekampet al. (2000) registered a highest force of 125 N, while Ferrario et al. (2004) registered a maximum force of 700 N. Such a variation could be understandable considering that the biting force determination depends on a number factors, including the location (Ferrairo et al. 2004), number of teeth (Gibbs, Anusavice, Young, Jones, & Esquivel-Upshaw, 2002), shape of the device used and compliance of its material.

Regarding the device location, Fontijn-Tekamp et al. (2000) measured the biting forces in pre-molars, canines and incisor in individuals with natural teeth, full dentures and overdentures (or fix dentures). Subjects with natural teeth were able to perform the highest biting force with the pre-molars (~110-125 N), followed by canines (~70-95 N), and incisors (~60-70 N).

The number of teeth included is another important influencing factor. With more teeth involved in the measurement, the assessment of the oral action could be more relevant to the reality. However, in dental studies, it is common to assess a single tooth or single position for the efficiency of oral tooth implants (Flanagan, Ilies, O'brien, McManus, and Larrow (2012).

Tortopidis et al. (1998) used three different shapes of the stainless steel force transducer to measure the biting force at different positions (Figure 4). These transducers used a similar model described by Lyons (1990), where two stainless steel beams with two strain gauges were attached to each side of the beam with flexible epoxy resin and wire to form a Wheatstone bridge circuit. The three transducers were designed in shape and pattern to fit the space between the second premolars and first molars on both sides (Figure 4a), between the anterior teeth (Figure 4b), and between the second premolar and first molars on one side (Figure 4c) (Tortopidis et al., 1998). The highest force was registered by the bilateral posterior transducer (580 N), and the lowest force was registered on the anterior transducer (286 N).

While different devices can be used for biting force measurements, devices that require considerable levels of mouth openings (more than 15 mm) are not desirable (Fernandes, Glantz, Svensson, & Bergmark, 2003). Recently, a flexi-sensor (with only 1 mm thickness) was reported for biting force measurement (Fernandes et al., 2003; Flanagan et al., 2012; Singhet al., 2011). This slim design has the great advantage of minimal inconvenience to the subjects during the biting test.

3.2.1.3 Tongue capability

The available techniques for studying tongue capability can be divided into techniques that measure the tongue-palate contact and techniques that study the tongue movement during oral processing and swallowing.

The tongue palate-contact refers to tongue pressing, an indication of the contraction strength of the tongue muscles. Devices for such measurements normally consist of the following two parts: a sensor inserted between the tongue and palate and a register for data recording. The Iowa Oral Performance Instrument (IOPI) (see Figure 5a) is a commonly used technique for this purpose, using a mobile plastic bulb to detect the strength of tongue pressing (Ono et al., 2009). The Handy Probe System is similar to the IOPI device, except that it uses a balloon instead (Figure 5e). A major problem of using the above devices is that they are inconvenient and uncomfortable due to the presence of a sizeable sensor inside the oral cavity, especially during swallowing. Potential measurement error can be caused by improper bulb placement inside the mouth (Butler et al., 2011). The design or multiple sensing probes (Figure 5c) involves where three (or even more) air filled bulbs that are arranged in a sequence (Tsuga et al., 2003). When the tongue presses the hard palate, pressures at different locations can be determined. A great advantage of this design is that it can measure pressure the profile rather than the pressure at a single point. However, a disadvantage is its inevitable interference with normal tongue movement.

A more sophisticated device for measuring the tongue pressure is the palatal plate with multi-sensors. Palates for measuring the tongue pressure during swallowing and mastication were created (see Figure 5b). Ono et al. (2009) combined palate design with the electromyography technique for simultaneous measurement of the tongue pressure and muscle activities. The approach was extremely useful in revealing the effects of denture wearing on swallowing for elderly people (Ono et al., 2009). However, real applications of palatal plates could be difficult because the prostheses require advanced techniques and are expensive to manufacture. Furthermore, subjects often find it very uncomfortable and usually need a period of time to obtain used to the plate. A sensor sheet (Figure 5d) consists of five measuring points, which are attached directly to the palatal mucosa with a sheet denture adhesive (Hori et al., 2009). The last two multisensors not only measure the tongue pressing strength, they also evaluate the tongue movement during mastication and swallowing initiation.

For a proper study of tongue movement during oral processing and swallowing, non-invasive imaging techniques, such as ultrasound imaging and videofluorography, have been reported in literature. Ultrasound has been used to study the coordination between the swallowing movement of the tongue and hyoid bone motion by placing pellets on two spots of the tongue as markers (Stone & Shawker, 1986); then, images are recorded and studied, frame by frame, for tongue movements (Böckler & Klajman, 1991). Videofluorography can also record the jaw and tongue movement, as has been demonstrated by Okada et al. (2007). Researchers gave subjects a stick of sushi rice containing a small amount of barium powder. To measure jaw gape, radiopaque markers were glued to the buccal surfaces of the upper and lower incisors and a calibrator was attached between the nose tip and upper lip so that the actual dimensions and movements of the organs in the videofluorography images can be calculated. In this way, researchers were able to record the jaw and tongue movement during the process of eating and swallowing. They found that most of the food was swallowed in the first swallow, and residual food was aggregated by the tongue into a bolus and then swallowed in the last swallow, a process often called oral clearance.

Although imaging techniques provide a good understanding of the tongue behaviour during the entire eating process, they are only qualitative, and the time required to complete the test and image analysis is superior to the tongue-palate contact tests. Additionally, the videofluorography technique may have concerns of safety and well-being for the subject due to radioactive exposure. For this reason, IOPI or a handy probe could be a good choice for assessing the tongue strength. The sheet sensor developed by Hori et al. (2009) allows for accurate measurement of the pressure at different points without dramatically interfering with mastication and swallowing. The great advantage of this technique compared with multiple sensing and palate sensors is the super thin sensor sheet, which can be flexibly adapted to the hard palate without causing too much inconvenience for the subject.

3.2.1.4 Orofacial muscle strength

Electromyography (EMG) is the most common method for monitoring activities and the strength of various orofacial muscles, especially those responsible for chewing (Yemm, 1977). EMG records live bioelectrical signals of the target orofacial muscle, such as the mandible elevator muscles (masseter and temporales) and mandible depressing muscles (digastrics). The former gives information about the closing phase of a chewing cycle, while the latter gives information about the mouth-opening phase of a chewing cycle. By analysing the EMG signals developed during the chewing cycle, one could assess the activities of chewing muscles and influences of food texture (Mioche, 2004). Many literature studies have been reported on this topic. Experimental set up and data analysis of the EMG technique can be found in a detailed review by Gonzalez and Chen (2012).

Orofacial muscle strength can also be reliably assessed in an indirect manner. For example, Alsanei and Chen (2014) measured the buccal muscular strength by assessing the maximum mouth volume. Subjects were asked to retain as much water in their mouths as they could from a cup container. Then, by recording the amount of the water inside the subject’s mouth, the maximum oral capacity can be calculated and, therefore, the strength of the orofacial muscles can be evaluated based on the assumption that good stretch-ability and elasticity of orofacial muscles (in particular, the cheek muscles) are essential for a maximum oral volume. In this work, it was shown that the maximum oral volume generally decreases as a function of age for the elderly populations. Furthermore, during the experiment, water dripping from the mouth corner was observed for some elderly subjects, which is a sign of poor lips sealing. It was concluded that all of these factors (a lower maximum volume capacity and lower capability of lip sealing) were effective indicators of weakened orofacial muscles that will affect one's capability of eating.

3.2.2 Masticatory capability

As was explained in section 2.2.1.2, the masticatory capability depends on many variables, such as the number of teeth, oral muscular force, oral coordination (open-jaw-swallow) and saliva secretion. Therefore, it makes sense that the masticatory capability should be assessed by collective measurements of these contributing parameters.

A convenient way to assess the masticatory capability is observing the efficiency of chewing some particular food that is either edible (e.g., peanuts, almonds, cocoa, carrots, jelly, hazelnuts, decaffeinated coffee beans, nuts, chewing gums or gelatin gels (Ahmad, 2006; Gambareli, Serra, Pereira, & Gavião, 2007; Schneider & Senger, 2002)) or non-edible, such as silicone-based artificial materials Optosil^{R}, OptocalPlus^{R} and CutterSil^{R} (Fontijn-Tekamp, Van Der Bilt, Abbink, & Bosman, 2004) and leaking-proof polyvinyl acetate capsules (de Abreu et al., 2014). The great advantages of silicone-based materials are that they are inert to water and saliva (they are not soluble or enzymatically active), homogenous (size, shape and toughness), lack seasonal variation, and can easily be stored (Fontijn-Tekamp et al., 2004). However, one large limitation is that these gels are not digestible and, therefore, must not be swallowed (Pocztaruk et al., 2008).

The methods for studying the degree of food fragmentation include sieving, colorimetric determination, and image analysis, which are often used to determine the particle size distribution. In all of these cases, the food is expectorated before swallowing and is then studied for the particle size distribution. In the sieving method, particles of a collected food bolus are carefully filtered through various mesh sizes. Then, the contents of the food particles at each sieve size are weighed and calculated as a percentage of the total weight. Van Der Bilt et al. (2008) compared the results obtained from a single sieving and multiple sieving method in 176 dentate subjects. They found that the single sieve method is less reliable than the multiple sieve method, although it involves less work compared to multiple sieving. Although it is relatively tedious and could involve some significant experimental error, the sieving method is still commonly used (Ahmad 2006). An alternative to sieving is the particle imaging method using an image analysis program (e.g., Image-Pro from MediaCybernetics), as has been used in several studies (Chen, Khandelwal, Liu, & Funami, 2013; Mowlana, Heath, Bilt, & Glas, 1994).

All assessment methods that require the mouth contents to be expectorated (i.e., spat out) before swallowing have the same disadvantage. Saliva and particles can accidentally be swallowed during chewing, which will cause inevitable experimental error. Yamashita, Sugita, and Matsuo (2013) found that part of the oral bolus may pass to the pharynx during mastication before a spontaneous swallow was initiated; therefore, only a portion of the “real” food bolus was collected.

For subjects who were not able to comminute the test food,Van Der Bilt et al. (2010) developed a gum kneading method. Instead of breaking up food, this method determines the masticatory capability by mixing/kneading of two differently coloured soft foods (e.g., chewing gums). The extent of colour mixing was measured as a function of the chewing cycles, and the masticatory efficiency of an individual can then be assessed. The authors (van der Bilt et al. 2010) concluded that the mixing/kneading ability test was effective and feasibly applicable to determine the masticatory function in subjects with a compromised masticatory performance (e.g., elderly subjects with denture). However, the method was not feasible for subjects with good masticatory performance (young subjects with natural teeth) because the task is too easy for them and it does not meaningfully distinguish among such subjects.

3.2.3 Swallowing capability

An objective assessment of the swallowing process is not an easy task. The clinical diagnosis of a swallowing disorder commonly uses techniques, such as videofluorography and fibertoptic endoscopy. The videofluorography technique has been used to study feeding models of dysphagia in pathological patients since 1980 (Ono et al., 2009). In the videofluoroscopy examination, fluid food of a certain consistency is mixed with barium and fed to the patient while the patient sits in the upright position (Langmore, 2003; Palmer et al., 2000). Radiography images are recorded when the subject swallows a barium marked bolus (Palmer et al., 2000). With videofluorography recording, the subjects' swallowing anatomic structures and motion of the food bolus can be observed and monitored (Palmer et al., 2000). By feeding patients food of different consistencies, the examiners are able to determine how capable the patient is of dealing with a bolus (Palmer et al., 2000). Ono et al. (2011) cited that the inability to demonstrate kinematical tongue biomechanics is a main limitation of videofluorography. Also the application of videofluorography to a healthy individual is considered to be unethical because of the radiation exposure (though it is well within the safe limit). Fiberoptic endoscopic evaluation of swallowing consists of a flexible trans-nasal laryngoscope entering deep in the oropharyngeal region. It has been used to evaluate the path of bolus entry and coordination during a normal meal (Dua, Ren, Bardan, Xie, & Shaker, 1997). The advantage of the trans-nasal endoscopy is that the results can be obtained in real time and with no oral invasion (and, therefore, no influence on tongue movement). Although both techniques are very useful for studying swallowing, the use of these techniques requires clinical qualification, making them less accessible for food scientists.

Koshino et al. (1997) reported on the use of ultrasound diagnostic equipment for studying bolus movement, the onset and offset of bolus flow, the bolus moving speed, and others. One great advantage of ultrasound measurements is that they are non-invasive. The attachment of ultrasound probes around the neck does not cause any noticeable impediment in bolus movement or in the actions of the tongue and other swallowing muscles. However, this technique is non quantitative and frame-by-frame image analysis is time consuming.

To the authors' knowledge, apart from the aforementioned techniques, no other technique is readily available for assessing the swallowing capability. As a compromise, the authors have used the tongue muscle strength as an indication of the swallowing capability based on the fact that tongue pressing generates the first pushing force for bolus flow. However, it must be noted that the tongue muscle strength measurement only provides information about the oral propulsive capability. This measurement cannot give any information about possible abnormalities that occur in the pharyngeal or oesophageal areas.

3.3 Sensing capability

To quantitatively assess an individual's sensing capabilities, threshold detection has been found to be the most practically feasible option. One's sensing capability can be assessed by the following three very different thresholds (Meilgaard et al., 2006): the absolute or detection threshold, recognition or identification threshold, and difference threshold. The absolute or detection threshold is the lowest intensity of a physical stimulus that is perceivable by the human senses of smell, taste, and tactile feeling. The recognition or identification threshold is the level at which a stimulus is not only detectable but also be recognised. The difference threshold represents the smallest change in stimulation that a person can detect.

Although these senses have a very different nature, the determination of their threshold shares the same approach as follows: an incrementing battery of intensities with a forced response of perception. For example, the absolute threshold in hearing refers to the smallest level of a tone that can be detected by normal hearing when there is no other interfering sound. For vision, the absolute threshold refers to the lowest level of light that a participant can detect.

In relation to food, the sensory thresholds to taste and odour are widely used. Various validated methods have been proposed by some authentic organizations, such as the American Society for Testing and Materials (ASTM) and International Organization for Standardization (ISO).

Tactile sensitivity is one of the most important physiological functions used for food texture sensation and perception. Unfortunately, tactile sensitivity has not been well studied in relation to eating and texture perception even though clinical studies have assessed patients with neuropathic illness and dental studies have evalauted oral tactile sensitivity (Hämmerle et al., 1995). Semmes-Weinstein monofilaments (SWMs) are probably the most commonly used technique for tactile sensitivity assessment (Selim et al., 2010). The technique has recently been successfully used in the authors' lab to assess reduced tactile sensitivity in elderly versus young people. Elderly people have significantly decreased tactile sensibility compared to young subjects (Laguna et al., 2015). Although it is logical to speculate that a decreased tactile sensitivity could mean a decreased capability of texture discrimination, experimental evidence to prove such a correlation is still lacking.

3.4. Mental and coordination capability measurements

The evaluation of the mental and coordination capabilities in relation to eating performance has been investigated from some very different perspectives. Psychologists assess the mental and coordination capability by identifying the eating behaviour problem, mostly through semi structured interviews (Cooper & Fairburn, 1987). The intelligence quotient was also used to assess and identify possible populations that are at risk for obesity (Emerson, 2005). Neuroscientists (Coluccini, Maini, Martelloni, Sgandurra, & Cioni, 2007) studied the grasp task in children with motor disorders using infrared cameras to record and analyse their body movement. Parameters, such as the total task duration and duration of each movement component (e.g., transport, reaching, grasp and release), have also been evaluated. Similarly, Hung et al. (2012) used an infrared technique to study the movements involved in grasping a biscuit and transport to the mouth. Apart from hand movement, the positions of the head, shoulder, elbow and bilateral wrist were also analysed. They reported that inappropriate rotation in the head and wrist caused eating difficulty in hemiplegic children.

Scientists from other medical areas, such as paediatrics and carers, used observational methodology to study the effect of disability on eating. Summers, Larkin, and Dewey (2008) conducted a study using parents as observers of children with developmental coordination disorders. Through focus group studies and interviews, they investigated the main problems children have in performing daily activities. A positive point of this study design is that the same environment was maintained throughout the study, and task-interactions occurred in most natural manner, which was close to real circumstances. However, the study is subjective overall, and few parents were interviewed. In their discussion, Summer et al. (2008) affirmed that a longitudinal, prospective study is needed; a standardized measure of their daily living performance in the context of the family is also needed.

Although scientists have been working hard to seek ideal methodologies or techniques for the quantitative assessment of mental and coordination capabilities in relation to eating and food consumption, no major, comprehensive method or technique has been reported. According to these authors, a key problem is the identification of measurement parameters that are closely related to eating and food oral consumption. Unfortunately, consensus about relevant parameters has yet to be reached. We hope that this review will stimulate more thinking on studying eating capability and inspire new ideas on the feasible assessment techniques for studies in this increasingly important area.

4. Summary

Many elderly people and dysphagia patients suffer from loss in their quality of life and malnutrition due to their diminished capability for eating. These vulnerable consumers (among others) have all sorts of problems in food handling, oral manipulation, sensing and perception as well as swallowing. The causes of these problems are either physiological or pathological. One of the top priorities for the food industry and carer industry is to provide food for that is safe for these consumers to eat.

This review proposes the concept of eating capability, aiming for the quantitative assessment of both the eating and food consumption capability of vulnerable consumers. The term consists of the following four main constituents: food handling, food oral manipulation, sensation, and cognition. The physical and physiological meanings of these parameters have been discussed based on abundant literature findings for all four aspects.

In this work, we demonstrated that it is scientifically viable to use some measureable parameters to represent and quantify the eating capability of an individual. To accomplish this, a number of techniques and methodologies have been discussed for their use as reliable assessments of the various components of the eating capability. Whenever possible, the advantages and limitations of such techniques have also been highlighted. We hope that this preliminary work will provide a knowledge base for assessing the eating capability of vulnerable consumers and useful guidance for the assessment techniques and methods. Looking forward, additional studies are needed to address the following topics: (1) establishing ideal technical solutions for the reliable, quantitative assessment of specific components of the eating capability; (2) the possibility of integrating four different components to form a single function of eating capability; and, more importantly, (3) the establishment of technical guidance in matching one’s capability of eating and the textural properties of food. Considering those topics, the aim of this review was to provide an introduction to the topic rather than an exhaustive summary of what has been achieved.

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