It's All in the Mime: Actions Speak Louder Than Words When Teaching the Cranial Nerves

Kerry Ann Dickson,[1]* **Bruce Warren Stephens**[2]
[1]*Discipline of Anatomy and Cell Biology, College of Health and Biomedicine, Victoria University, Melbourne, Victoria, Australia*
[2]*Department of Econometrics and Business Statistics, Monash University, Melbourne, Victoria, Australia*

Cranial nerve (CN) knowledge is essential for students in health professions. Gestures and body movements (e.g., mime) have been shown to improve cognition and satisfaction with anatomy teaching. The aim of this pilot study was to compare the effectiveness of didactic lecturing with that of miming lecturing for student learning of the CNs. The research design involved exposure of the same group of students to didactic followed by miming lecturing of CNs. The effectiveness of each lecturing strategy was measured via pre- and post-testing. Student perceptions of these strategies were measured by a survey. As an example of miming, gestures for CN VII included funny faces for muscles of facial expression, kangaroo vocalization for taste, spitting action for saliva production, and crying for lacrimal gland production. Accounting for extra duration of the miming lecture, it was shown that pre- to post-test improvement was higher for the miming presentation than for the didactic (0.47 ± 0.03 marks/minute versus 0.33 ± 0.03, $n = 39$, $P < 0.005$). Students perceived that the miming lecture was more interactive, engaging, effective, and motivating to attend (mean on five-point Likert scale: 4.62, 4.64, 4.56, 4.31, respectively) than the didactic lecture. In the final examination, performance was better ($P < 0.001$, $n = 39$) on the CN than on the non-CN questions—particularly for students scoring $\leq 60\%$. While mediating factors need elucidation (e.g., learning due to repetition of content), this study's findings support the theory that gestures and body movements help learners to acquire anatomical knowledge. Anat Sci Educ 8: 584–592.

Key words: gross anatomy education; undergraduate education; active learning; kinesthetic learning; gestures and body movement; cranial nerves; embodied cognition; psychomotor functions

INTRODUCTION

One of the greatest challenges facing anatomy educators is engaging students and motivating them to learn (Terrel, 2006). This is particularly so if the cohort is diverse in terms of their aptitude, engagement, metacognitive skills, non-academic responsibilities and financial constraints; the curriculum contains voluminous content taught in fewer hours; the content is prerequisite knowledge for an array of postgraduate medical and health programs; and resources and budgets are tight. Many students and teachers view anatomy as a list of structures that needs to be learned by rote, devoid of intrinsic interest and divorced from the clinical setting. However, if anatomy is taught in a novel way, students respond enthusiastically and learning is often enhanced (Sugand et al., 2010; Drake and Pawlina, 2014).

Innovative Kinesthetic Anatomy Learning

Effective teaching strategies should be learner-centered and interactive; focus on concepts; integrate structure and

*Correspondence to: Associate Professor Kerry Dickson, Discipline of Anatomy and Cell Biology, College of Health and Biomedicine, Victoria University, St Albans Campus, PO Box 14428, Melbourne, Victoria, Australia.
E-mail: Kerry.dickson@vu.edu.au

Received 31 October 2014; Revised 27 January 2015; Accepted 6 March 2015.

Published 2015 Wiley Periodicals, Inc.

function; embed clinical significance; concentrate on spatial relationships; and accommodate to visual, auditory, and kinesthetic learners (Terrell, 2006; van Merriënboer and Sweller, 2010; Drake and Pawlina, 2014). Several authors have developed innovative kinesthetic strategies to teach anatomy. Everyday items (e.g., wire, tubing) have been used to construct models representing anatomical structures, including the abdominal vasculature (Zumwalt et al., 2010), spinal cord (Skinder-Meredith, 2010) and inguinal canal (Serrat et al., 2014). Hands-on anatomy has also been taught using board games (Anyanwu, 2014), clay modeling (Skinder-Meredith, 2010; Kooloos et al., 2014), and body painting (McMenamin, 2008; Skinder-Meredith, 2010). Gestures and body movements have been used in anatomy education for some time (Cobb, 1972). However, their use has only fairly recently been shown to improve student engagement (Nayak, 2006; Oh et al., 2011; Dickson and Stephens, 2014) and learning (Macken and Ginns, 2014).

Gesture-based Learning and Anatomy

Mime is the non-verbal technique of portraying a character, mood, idea or narration by gesture and body movements. It lies on a continuum: from gesticulation (spontaneous movements accompanying speech), gestures, mime, and emblems (conventional culturally specific gestures) to sign language for the hearing-impaired (Roth, 2001). Gestures (i.e., movements of the hands, limbs, face or body—which do not involve directly manipulating objects) have been shown to improve learning (Roth, 2001; Barsalou 2008; Goldin-Meadow, 2011; Cartmill et al., 2012; Cook et al., 2012; Ionescu and Vasc, 2014; Xu and Ke, 2014). Evidence of the role of the motor system in cognition has led to new areas of research, including grounded cognition (Barsalou, 2008) and embodied cognition (Goldin-Meadow, 2011; Cartmill et al., 2012).

Although there are variations in taxonomy, gestures include deictic, which draw attention by pointing; representational, which convey concrete items; and metaphorical, which convey concepts (Roth, 2001; Cartmill et al., 2012). Gesture-based learning has been investigated in several disciplines, particularly language and mathematics (Barsalou, 2008). Alibali and Nathan (2012) list examples of gestures in mathematics: deictic (pointing to a cube), representational (tracing a triangle in the air) and metaphoric (moving the arm back and forth to signify oscillations). Compared with conventional teaching, using purposeful body movements (e.g., a group of children forming a circle with their bodies to learn about shapes and angles) has been shown to improve learning of mathematics (Shoval, 2011). Novack et al. (2014) measured learning via direct manipulation of number tiles and via gestures. They found that gesturing, in particular metaphorical gestures, led to deeper learning of mathematical concepts in primary school children.

Nayak (2006) found that students enjoyed a scenario where covering a student's body with a blanket represented the peritoneal coverings of the female reproductive organs. An innovative form of anatomical teaching—using the hands and digits to represent arteries, veins, and nerves—has been developed for medical students (Oh et al., 2011). Five-point Likert scores (mean 4.2) showed high student satisfaction with the teaching method. Students considered that the gestures helped them to understand and memorize the structures (4.1 and 4.0, respectively), (Oh et al., 2011). However, the efficacy of the gestures for learning remains to be elucidated via a controlled study. In 2014, Dickson and Stephens used gestures to teach the musculoskeletal system to large and diverse cohorts of nursing students. The gestures included deictic (e.g., pointing to bones on one's body); representational (e.g., kinesthetic mnemonics where students used their hands to represent the shapes of articulating surfaces) and metaphorical (e.g., en masse synchronous "Mexican wave" to illustrate nerve impulses). Although student satisfaction with the teaching method was very high (Likert score: 4.9), the effectiveness of the teaching approach was not tested (Dickson and Stephens, 2014).

Using cognitive load theory and embodied cognition as their theoretical basis, Macken and Ginns (2014) investigated whether use of gestures enhanced learning of anatomy and physiology. After pre-testing physiological knowledge of the heart, they instructed their education students to either point to and trace anatomical structures, or to sit on their hands. They found that the deictic gestures resulted in a 26% and 18% improvement in terminology and comprehension, respectively (Macken and Ginns, 2014). However, generalizability of these results is limited as the students were not studying bioscience, nor is learning while sitting on one's hands a common occurrence.

Learning of Cranial Nerves

Learning the anatomy, physiology and clinical assessment of the cranial nerves (CNs) is challenging, as many of the nerves have an intricate structure and complex functions. Traditionally, CNs have been taught using two-dimensional (2D) images in a didactic lecture, in combination with plastic models or cadaver material in a hands-on laboratory class. As CN content is difficult, academics have used a range of strategies to engage students, including 3D virtual simulations (Yeung et al., 2011, 2012; Nowinski et al., 2012, Johnson et al., 2013), gaming avatars (Richardson-Hatcher et al., 2014), videos (Azer et al., 2012), models (Zhang and He, 2010), games (Jones et al., 2000), songs (Bromfield, 2008; Williams, 2009), and drawings (Bolek, 2006). However, evidence of these strategies' effectiveness in improving CN knowledge is limited.

Over 40 years ago, Cobb (1972) encouraged teachers to convey CN functions using eight mimetics, noting that it would take only 16 seconds away from lecture content and was a fun way to stimulate recall. However, the article provides no evidence of the effectiveness of miming. The aim of the present pilot study was to compare the effectiveness of didactic lecturing with that of miming lecturing for student learning of the CNs.

METHODS

Biomedical Science Curriculum

The biomedical science students in this study attended Victoria University (VU), a low-ranked Australian university. There is a very high percentage of biomedical science students who are disadvantaged, e.g., under-achieving, first in the family to attend university, non-English home language, migrant or low socioeconomic status. To help these students, teaching faculty have embedded explicit teaching practices into first year and introduced professional development programs for teachers (Tangalakis et al., 2014).

In the Biomedical Science program, students gain in-depth knowledge of human anatomy and physiology, combined

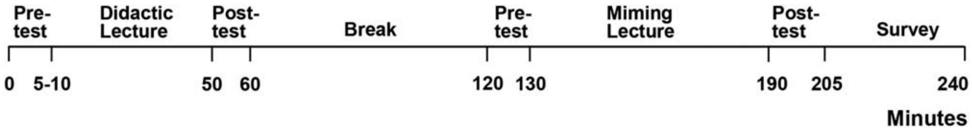

Figure 1.

A lecture roll was taken at 9:00AM (0 minute) on the day of the experiment. The same CN test was given four times to the same group of 39 students: before and after the didactic lecture, then before and after the miming lecture. There was a break between the two types of lecture. The survey was completed after the final test.

with skills in critical analysis and communication. In first year, students study an anatomy unit on the trunk followed by one on the limbs. In second year, they study head, neck and back followed by a unit on rehabilitation. The second year units are approved as prerequisites for postgraduate medicine at Australia's highest-ranked university. In third year, students may elect to complete a cadaver dissection as part of a research project. The degree leads to further study in science, medicine and allied health, or to employment in a range of areas, e.g., laboratory specialist, science journalist, wellness consultant. Within the Biomedical Science degree, the total hours of regional anatomy taught, the use of models and prosections in every laboratory session, the delivery of teaching primarily by casual assistants, and the availability of dissecting an anatomical region as an optional elective, are comparable to anatomy units in medical degrees at universities in Australia and New Zealand (Craig et al., 2010). However, students have limited exposure, within the laboratory setting, to medical imaging and surface anatomy.

Head, Neck, and Back Curriculum

The students in this study were enrolled in the second year anatomy unit which covers head, neck and back. The unit (60 total face-to-face hours) covers functional gross anatomy and histology. There were 36 hours of voluntary lectures which utilized PowerPoint presentations and interactive-learning strategies. Lectures were given on the same day each week (9:00–10:00 AM and 11:00 AM–1:00 PM). There were 24 hours of compulsory laboratory, including the use of cadaver prosections, models, bones, slides and videos. Students worked collaboratively in the laboratory to complete activities which often included games and student presentations. All teaching material was uploaded to a learning management system. Assessment in the unit consisted of two short tests, a 3-hour theory examination and a 2-hour practical examination. The theory examination consisted of multiple-choice questions (MCQ) and short answer questions (SAQ). In the prerequisite unit, studied eight months earlier and covering anatomy of the trunk, students were briefly introduced to the nervous system and CNs—particularly the vagus nerve. As both units were taught by the same instructor, students had developed a familiarity with the lecturing style and scores for 'Overall satisfaction with the teacher' were high (five-point Likert score: ≥ 4.8).

Pre- and Post-tests

On the day of experimentation, a lecture roll was taken at 9:00 AM and 39 of 53 students enrolled in the unit were present (74%). Fourteen students were either late or absent from the lectures. These 14 students were not issued with the tests and survey and, thus, did not form part of this study.

The same anonymous CN test was given four times on that day to the same group of 39 students: before and after the didactic lecture, then before and after the miming lecture which followed. There was a break between the two types of lecture. The anonymous survey was completed after the final test (Fig. 1).

In keeping with the design principles of van Merriënboer and Sweller (2010), pre- and post-tests asked students to write as much as they could about the structure and function of the CNs. Although no time limit was imposed, students finished within 5–15 minutes. Pre- to post-test difference measured CN learning during the lecture.

Students were exposed to the same content in the didactic and the miming lectures, the same PowerPoint slides being used in each delivery. Thus, the experimental design did not account for learning in response to repeated exposure to CN content. Lecture content included the major branches (e.g., V_1), exit pathways (e.g., cribriform plate) and functions (e.g., muscles of facial expression). In the miming lecture, the CN actions were demonstrated to, and then performed by, the students. Table 1 summarizes the miming actions used in teaching the CNs. As the actions were quite complex (especially for CNs V, VII, IX, and X), several repetitions were performed, building up in a sequential fashion to all 12 CNs. The full sequence was then performed several times, and at increasing speed, by the students—with and without the instructor. As interactive lecturing is more time-consuming than didactic (Miller and Metz, 2014), the teaching faculty addressed the potential effect of extra delivery time (i.e., time on task) on the improvement in learning by analyzing pre- to post-test score differences relative to lecture duration. An alternative would have been to lengthen the didactic lecture. However, this may have led to students losing attention—possibly yielding a negative effect on learning.

Survey Instrument

A survey was used to determine the level of student satisfaction with the miming lecture compared with the didactic presentation. All 39 students completed the voluntary survey, which consisted of 14 items scored on a five-point Likert scale (strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, strongly disagree = 1). The survey areas of interest were the levels of interaction, engagement, effectiveness, motivation to attend, and challenge. Of the 14 survey items, eight were positively-keyed and three were negatively-keyed. Examples of the form of the items were "I found the normal/didactic lecturing approach very engaging." and "Compared

Table 1.

Summary of Cranial Nerve Miming Actions

Number	Cranial nerve	Nerve function	Miming action
I	Olfactory	• Smell	• Sniffing a large breath, circulating arms in front of body
II	Optic	• Vision	• Hands forming tunnels in front of eyes
III	Oculomotor	• Eye muscles	• Index finger circling eyes
		• Pupil constriction (parasympathetic)	• Hands over eyes to simulate darkness
IV	Trochlear	• Eye muscle: superior oblique	• Index finger circling eyes, tapping superior and lateral part of orbit
V	Trigeminal		
	Ophthalmic	• Skin sensation on forehead, maxilla and mandible	• Tapping forehead, upper and lower jaws—indicating branches of nerve
	Maxillary	• Mucosa sensation of eye, nose and mouth	• Simulation of inserting a contact lens, picking nose and tongue-kissing
	Mandibular	• Muscles of mastication	• Chewing
VI	Abducens	• Eye muscle: lateral rectus	• Index finger circling eyes, tapping lateral part of orbit
VII	Facial	• Muscles of facial expression	• Pulling funny faces, fingers indicating branches of nerve
		• Taste sensation for anterior 2/3 of tongue	• Kangaroo vocalization to simulate tasting food
		• Saliva production of sublingual and submandibular glands (parasympathetic)	• Sucking saliva into mouth and pretending to spit, while touching under jaw and tongue
		• Tear production from lacrimal gland (parasympathetic)	• Crying
VIII	Vestibulocochlear		
	Cochlear	• Hearing	• Placing hand behind ear
	Vestibular	• Balance	• Swaying body
IX	Glossopharyngeal	• Pharyngeal muscles	• Swallowing
		• Sensation for pharyngeal mucosa and posterior 1/3 of tongue	• Simulating gag reflex
		• Carotid body and sinus innervation	• Fingers to common carotid bifurcation
		• Taste sensation for posterior 1/3 of tongue	• Kangaroo vocalization to simulate tasting food
		• Saliva production of parotid gland (parasympathetic)	• Sucking saliva into mouth and pretending to spit, while touching side of face
X	Vagus	• Pharyngeal muscles	• Swallowing
		• Laryngeal muscles	• Saying "chatter, chatter"
		• Taste sensation from epiglottis	• Kangaroo vocalization to simulate tasting food
		• Sensory and motor to smooth muscle and glands in organs of thorax and abdomen (parasympathetic)	• Pounding heart with hand, deep breathing and wringing hands above abdomen
XI	Spinal accessory	• Sternocleidomastoid and trapezius muscles	• Flexing and extending head
XII	Hypoglossal	• Major tongue muscles	• Poking out tongue

Figure 2.

Students engaged in miming using a representational gesture (funny faces to signify innervation of the muscles of facial expression) in the upper image and a metaphorical gesture (hands over eyes to simulate parasympathetic oculomotor innervation for pupil constriction) in the lower image.

with the normal/didactic lecturing approach, I found the hands-on/miming approach more interactive". The data from the latter form were used in the presentation of the results.

Examination Performance

Learning of CNs for examination purposes was measured by comparing performance on CN and non-CN SAQ in the final theory examination (10 weeks after the CN lectures). The rationale here is that students were able to recall the miming actions in order to answer the CN SAQ, but lacked this resource for answering the non-CN SAQ. Thus, if learning was unchanged by miming, the ratio of marks on CN SAQ to marks on non-CN SAQ would be expected to equal one. The CN to non-CN ratio was calculated for the 39 students who attended both the didactic and the miming lecture. The ratios of the 14 students who were late or absent from the didactic and miming lectures were excluded from the analysis because their degree of exposure to miming was unknown. For example, at least four of the 14 students were late but enthusiastically engaged in the miming lecture.

Student Demographics

Students' age, sex, and home address zip code were obtained from institutional records. Socioeconomic status was determined, via zip code, from the national index of disadvantage. This study received approval from the Victoria University Human Research Ethics Committee (VUHREC).

Statistical Analysis

Scores on the four tests (didactic pre- and post-tests; miming pre- and post-tests) were compared using a repeated measures, one-way ANOVA with Tukey–Kramer post hoc comparisons. After accounting for lecture duration, changes (mark/minute of lecture) in pre- to post-test marks for the didactic lecture were compared with the corresponding changes for the miming lecture, via a one-tailed paired t-test. Reliability of the survey was tested using Cronbach's alpha, values of at least 0.7–0.8 being considered an acceptable criterion for reliability. Validity was shown by significant correlations in Kendall's tau-b analysis. Wilcoxon's signed rank procedure was used to test whether the median scores for the survey exceeded 3 (neither agree nor disagree) on five-point Likert scale. Differences in students' perceived levels of interaction, engagement, effectiveness and motivation to attend were compared using Friedman's non-parametric test. Post hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied. For the final examination, the difference between students' performance on CN and non-CN questions was analyzed via a one-tailed paired t-test. The relationship of final mark and student demographic variables (age, sex, socio-economic status) to the CN versus non-CN ratio was analyzed via multiple regression analysis. For different final mark groups ($\leq 60\%$, 61–79%, $\geq 80\%$), the CN versus non-CN ratio on the final examination was analyzed by one-way ANOVA. All tests were conducted in Statistical Package for Social Scientists (SPSS), version 22, for Windows (IBM, Armonk, NY), except for the Tukey–Kramer

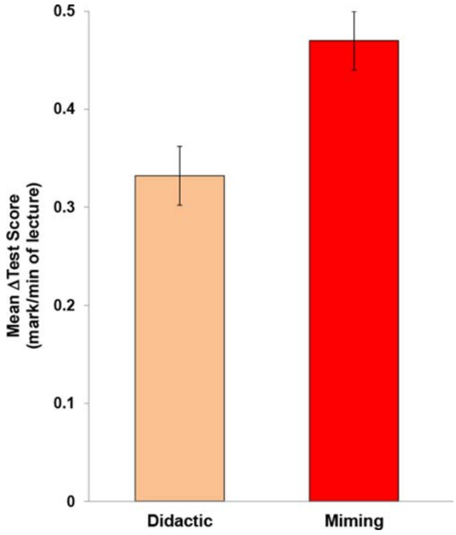

Figure 3.

Difference in pre- and post-test scores, relative to lecture duration (mean ± SEM), for didactic and for miming lecturing ($n = 39$). Improvement in scores was 42% better with miming than with didactic lecturing.

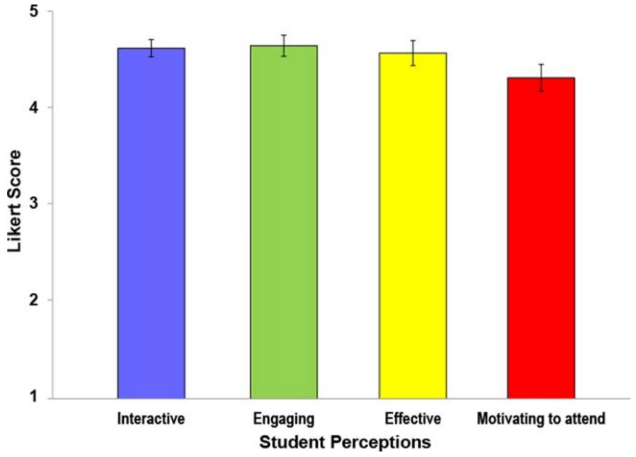

Figure 4.

Student perceptions of miming lectures. Students agreed or strongly agreed that they found miming to be more interactive, engaging, effective and motivating to attend (95%, 89%, 86%, and 76% of students, respectively) than didactic lecturing. Results expressed in the five-point Likert scores were: strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, strongly disagree = 1; mean ± SEM.

post hoc comparisons which were performed using Microsoft Excel (Microsoft, Redmond, WA).

RESULTS

Of the 39 students, 69.2% were ≤22 years; 64.1% were female; and 41.0% were low, 25.6% medium and 33.3% high socioeconomic status. Figure 2 shows students engaged in miming. Post-test scores were significantly ($P < 0.01$) higher than the corresponding pre-test scores for both the didactic (18.5 ± 1.3 versus 5.3 ± 0.6) and miming (44.3 ± 2.5 versus 16.1 ± 1.1) lectures. There was no significant difference between the didactic post-test and the miming pre-test. After accounting for lecture duration, pre- to post-test improvement (mark/minute of lecture, $n = 39$) was higher ($P < 0.005$) for the miming presentation than for the didactic (Fig. 3).

Cronbach's alpha and Kendall's tau-b analyses showed that the survey was, respectively, reliable and valid. Cronbach's alpha was 0.851 but, with removal of the three items related to challenge and one related to motivation to attend, alpha increased to 0.917. Kendall's tau-b analysis revealed significant ($P < 0.05$) pairwise correlational relationships amongst all remaining ten items in the survey. Pairwise relationships among the four items interaction, engagement, effectiveness and motivation to attend were all significant ($P < 0.0001$): interaction and engagement ($r = 0.616$); interaction and effectiveness ($r = 0.616$); interaction and motivation to attend ($r = 0.554$); engagement and effectiveness ($r = 0.766$); engagement and motivation to attend ($r = 0.575$); and effectiveness and motivation to attend ($r = 0.614$).

There was no significant difference in the students' perceived level of challenge between the two delivery approaches. Compared with the didactic lecturing, students perceived the miming approach to be more ($P < 0.001$) interactive, engaging, effective and motivating to attend (Fig. 4). There was a statistically significant difference in the responses to these four items ($P < 0.01$), with motivation to attend being lower ($P < 0.05$) than the other three. In the open-ended section of the survey, students commented that miming "was the best way to learn something difficult," "allowed students to feel what was being covered, by actually performing the task," "was much more effective," "challenged students to remember movements,

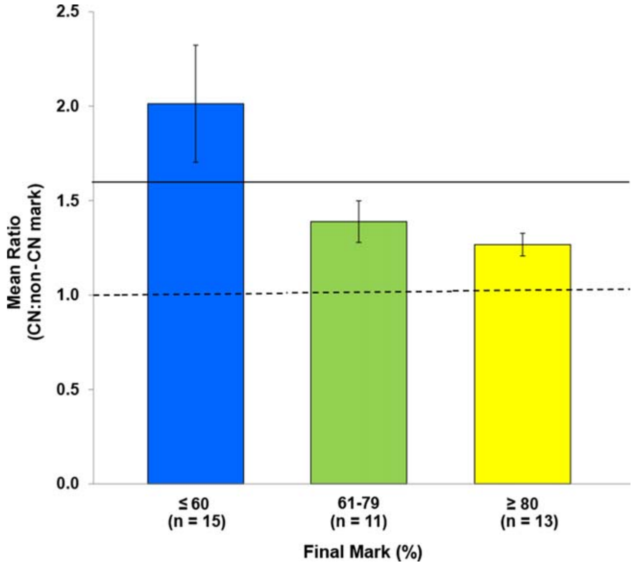

Figure 5.

Relationship between the mean CN versus non-CN ratio on the final examination and student final mark for the unit. The mean ratio overall (solid line, $n = 39$) and the expected ratio of one (dashed line) are shown.

making it more fun," "was visual, repetitive, interactive" and "allowed absorption of a lot of information."

At the final examination, 10 weeks after the CN lectures, performance was higher on the CN than on the non-CN questions (74.0% ± 3.8% versus 52.9% ± 3.5%, $n = 39$, $P < 0.001$). Thus, the overall mean (1.59 ± 0.13) of the CN to non-CN ratios was significantly higher ($P < 0.001$) than the expected ratio of one (Fig. 5). The CN to non-CN ratio did not differ significantly with age, sex or socioeconomic status, but it was negatively related to final mark ($P < 0.001$). For students with a final mark ≤60%, the ratio was significantly higher ($P < 0.05$) than for students scoring ≥80% (Fig. 5).

DISCUSSION

The present study found that, compared with didactic lecturing, differences in the pre- to post-test scores were greater with student miming of the CNs. It was also found that, compared with didactic lecturing, students perceived miming the CNs to have greater interactivity, engagement, effectiveness, and motivation to attend. The learning for examination purposes was greater for CN than for non-CN content, particularly for under-achieving students. The preliminary findings from this study support the contention that gestures and body movements (such as those associated with miming) help learners to acquire anatomical knowledge. However, mediating factors (e.g., the learning due to repetition of CN content) need to be further elucidated.

Gesture-based Learning and Anatomy

Earlier work examining the effect of gestures on anatomy learning considered only deictic (Macken and Ginns, 2014) or only representational (Oh et al., 2011). However, in the present study, miming of the CNs involved a complex array of gestures. These included deictic (e.g., tapping forehead, upper jaw and lower jaw to indicate branches of the trigeminal nerve), representational (e.g., making funny faces to signify innervation of the muscles of facial expression) and metaphorical (e.g., hands covering the eyes to simulate variation in light intensity—evoking the parasympathetic innervation of the oculomotor nerve which is responsible for pupil constriction). Students were capable of performing the complex motor sequence involved in miming the CNs. The miming was dynamic—with students requesting faster and faster repetitions of the 12 CN sequences, without teacher participation, in order to consolidate their learning.

Based primarily on the taxonomy of Bloom et al., learning has been categorized into cognitive (knowledge, thinking), affective (attitude, emotion) and psychomotor (skills, doing) domains (Anderson et al., 2001). In the present study, students' comments indicated that miming aroused positive emotions, such as curiosity, amusement, pride in achievement, and collegiality—performing the actions together as a unit and correcting mistakes collaboratively. Thus, it is possible that the improvement found in student learning was facilitated through the affective domain.

Psychomotor learning is exemplified by physical movement, coordination and motor skills—as observed in routine activities like driving a car, and in musical or athletic performances. Over the last decade or so, evidence has mounted that the relationship between motor and learning is bi-directional. Evidence suggests that cognition is influenced by movement, including gestures and body movements (Roth, 2001; Barsalou 2008; Goldin-Meadow, 2011; Cartmill et al., 2012; Xu and Ke, 2014). This has led to several theories including motorpsycho (Xu and Ke, 2014), embodied cognition (Goldin-Meadow, 2011; Cartmill et al., 2012) and grounded cognition (Barsalou, 2008). Although there is some controversy between these theories, they basically emphasize the role of movement and gestures in helping learners to acquire cognitive knowledge. It is thought that gestures facilitate information-processing by attracting attention, by invoking multimodal sensors, by reducing cognitive load, and by enhancing information encoding and concept concretization (Xu and Ke, 2014). It is possible that miming may have facilitated learning via each of these mechanisms.

Information-processing theory categorizes memory as sensory, working (short-term) and long-term. Sensory memory (e.g., visual/iconic, aural/echoic and touch/haptic) is stronger when the stimulus captures attention and involves more than one sense (Xu and Ke, 2014). Kooloos et al. (2014) found that pre- to post-test improvement in score was 22% greater with live observation of a clay modeling anatomical demonstration than with student hands-on manipulation, but that this finding was not replicated if the demonstration was by video. They suggest that focused attention is a stronger stimulus for learning than is haptic stimulation. In the present study, the attention-getting nature of the miming lecture was suggested by the survey result that 95% of students strongly agreed or agreed that the miming lecture was more interactive than the didactic lecture.

Miming epitomizes multimodal active learning because students must think ahead about the functions of the CNs, visualizing their spatial pathways before performing the gestures. Innovative strategies in anatomy, which capture students' attention by using hands-on techniques, have been shown to be enjoyable and helpful to learning (McMenamin, 2008; Skinder-Meredith, 2010; Anyanwu, 2014; Serrat et al., 2014). Body painting of the torso, upper limb and face (McMenamin, 2008) and clay modeling of the larynx (Skinder-Meredith, 2010) have been found to be enjoyable (five-point Likert score: 3.59 and 4.22, respectively) and useful learning experiences (3.57 and 4.49, respectively). In the present study, the engagement (4.64) and effectiveness (4.56) scores (miming compared with didactic lecturing) were higher than the scores of McMenamin (2008) and Skinder-Meredith (2010) for enjoyment and usefulness. Anyanwu (2014) found that the pre- to post-test improvement in marks (over a 10-day period) was 90.3% greater with an anatomical board game than without the game. When similarly not accounting for time on task, the authors of the present study found that the improvement in marks was 113.6% greater with miming than with didactic lecturing. In combination with previous work, this pilot study may suggest that adult learning is greater when using gestures than when directly manipulating anatomical models—similar to what was found for children using tiles for studying mathematics (Novack et al., 2014). However, this is an area for further study.

Working memory is responsible for transient holding and processing of information, and is limited in its capacity and duration. Particularly when content to be learned is complex (intrinsic load), cognitive load theorists (van Merriënboer and Sweller, 2010) design their teaching material to limit external interference (extraneous load)—thus maximizing students' working memory capacity for processing relevant information and integrating it into long-term memory (germane load). Although controversial (Caramazza et al., 2014), embodied cognition theory argues that learning by imitating the teacher's words and actions is effective because motor neuronal pathways (mirror neuron system) are activated (Rizzolatti and Sinigaglia, 2010)—possibly freeing up working memory (Goldin-Meadow, 2011; Cook et al., 2012). In 2014, Macken and Ginns measured student self-reporting of cognitive load while learning the anatomy and physiology of the heart via pointing and tracing gestures. Intrinsic load was indicated from survey items about the level of content complexity, extraneous load by the level of difficulty to learn, and germane load by the level of concentration. They hypothesized that gestures would lower extraneous, raise germane and not affect intrinsic load and found no significant differences in the three types of load between learning with, and without, gestures. Cognitive load was not measured in the present study. However, there was no difference in student perceptions of the level of challenge (indicative of intrinsic load) between the lecture content with, and without, miming gestures.

Long-term memory is classified as either declarative (explicit; conscious; facts and events) or procedural (implicit; unconscious; motor skills and tasks) with respective neuronal pathways which were thought to be separate. However, the declarative (primarily the hippocampus) and the procedural (primarily the striatum) systems have been shown to overlap (Albouy et al., 2013)—possibly strengthening the argument that the relationship between movement and cognition may be bi-directional. Oh et al. (2011) required students to practice, throughout their course of anatomy study, sets of hand movements which represented complex arrangements of vessels and nerves. Students perceived the most helpful representation to be the set comprising the aortic arch, subclavian, and axillary arteries. The authors concluded that one reason for this may be that these vessels were repeatedly taught in several sections of their course. As repeating a movement over time invokes motor memory (a form of procedural memory), the authors postulated that invoking a motor memory may help to improve learning of anatomy. In the present study, students were not required to practice the miming actions for the CNs beyond the day of teaching the miming sequence. Neither did teaching faculty document whether individual students repeated the movements during the 10 weeks up to the examination. Nevertheless, it was found that examination performance was better for CN than for non-CN content. It is possible that miming enhanced the learning of CN knowledge by invoking motor memory—retrieving a mental "snapshot" of the miming actions.

Learning of Cranial Nerves

Zhang and He (2010) designed a simple, inexpensive model of the eye and showed that its use improved student understanding of CN III, IV, and VI. In their qualitative evaluation of a "CN Wheel of Competencies" game, Jones et al. (2000) found that participants perceived the game to be preferable to a written test—as it was fun, effective and non-intimidating. A drawing of a face with numbers marking CN innervated structures (Bolek, 2006), mnemonics, limericks and songs (such as "CN Boogie," Bromfield, 2008) are available, but their effectiveness in improving CN knowledge has not been tested. This current study extends the early work of Cobb (1972) by increasing the number of miming actions; by changing from instructor demonstration to student participation; and by measuring student engagement and performance. It was found that the simple technique of miming was an easily-implemented, highly engaging, teaching strategy which enhanced student learning of the CNs.

In contrast to the traditional mode of 2D images in a didactic lecture, several authors have developed innovative, online strategies to teach the CNs. Yeung et al. (2011) developed a simulator which provided an exciting 3D roller-coaster view of the CNs from origin to innervated structures. Using a randomized, blind design, they compared students who used the simulator with those who used a 2D text- and image-based document, finding no difference in students' knowledge of CN III (Yeung et al., 2012). Nowinski et al. (2012) developed a virtual interactive atlas of the CNs which allowed individual color-coded structures to be labeled and fully manipulated in 3D. Using virtual patients to simulate CN palsies, Johnson et al. (2013) showed that their simulator improved the performance of weaker students, when they worked in teams. Recently, an innovative virtual anatomy program has been developed in Second Life^{TM}—using 2D and 3D images plus an avatar—to teach the structure and function of CN III, V, VII and IX (Richardson-Hatcher et al., 2014). Uptake of the program was around 80% but <50% of students thought that it improved their understanding. Although good quality CN videos are available on YouTube, finding them is difficult and time-consuming (Azer et al., 2012). Online resources provide an exciting new facet of medical education but, as yet, many have not been tested for their impact on student learning (Terrell, 2006). Future studies using 3D body sensory technologies, such as Microsoft Kinect (Microsoft Corp., Redmond, WA), (Xu and Ke, 2014), may be able to combine gesture-based learning, as piloted in the present study, with digital technologies.

Limitations of the Study

This pilot study has several limitations. The same lecture was given twice: without, then with, miming. Thus, the current study design cannot distinguish improved performance due to miming from that due to repetition of CN content. Comparisons between pre- and post-test scores need to be confirmed by using either a full cross-over study or two comparable groups of students: one group exposed to didactic lecturing, the other to miming. Only then one would be able to conclude if CN and non-CN ratios were higher for students exposed to miming than for students never exposed to CN miming. Neither the teacher nor the students were blind to the intervention. Differences in the quality of delivery of the didactic and miming lectures may have influenced results. Student preference for interactive, fun lectures may have biased the post-test scores. The non-cognitive (affective and psychomotor) domains were not accounted for in this study. Potentially relevant factors include metacognition, motivation, and sense of responsibility for learning. Students' skills at miming were not measured, nor was their use of miming for examination preparation recorded. Hence, the interpretation relating to gesture-based learning of CN knowledge is very preliminary and requires affirmation by further work. Although the authors endeavored to account for learning due to time on task, by expressing differences in test scores relative to lecture duration, this study needs to be repeated with equal lecture duration. The miming involved a complex array of deictic, representational and metaphorical gestures, compounding any interpretation of gesture-based learning effects.

Although valid and reliable, the survey implemented in this study was rudimentary. The survey did not ask students about their attention levels nor did it measure the three domains of cognitive load. The study was carried out on a small number of participants, in only one anatomy unit, at a single institution—limiting the generalization of the findings. There was an hour break between the didactic and miming lecture which may have influenced students' receptiveness to learning. Finally, the miming approach may not be easily transferable to disciplines other than anatomy and physiology.

CONCLUSION

Gestures and body movements (e.g., mime) have been shown to improve learning. After learning the CNs via deictic, representational and metaphorical gestures, students responded by performing the complex sequence, without teacher participation. When accounting for time on task, it was found that improvement in marks was 42% better with miming than with didactic lecturing. Students agreed or strongly agreed that they found miming to be more interactive, engaging, effective and motivating to attend than didactic lecturing. It was also found that learning for examination purposes was greater for CN than non-CN content, particularly for underachieving students. The preliminary findings of the present study support the contention that gestures and body movements (such as those associated with miming) help learners to acquire anatomical knowledge. However, mediating factors (e.g., learning due to repetition of content) need to be further elucidated.

NOTES ON CONTRIBUTORS

KERRY DICKSON, Ph.D., is an associate professor in the Discipline of Anatomy and Cell Biology in the College of Health and Biomedicine at Victoria University, Melbourne, Australia. She teaches anatomy and physiology to biomedical science, nursing and health science students.

BRUCE STEPHENS, M.Stat., is a lecturer in the Department of Econometrics and Business Statistics at Monash University, Melbourne, Australia. He teaches statistics and mathematics to business students.

LITERATURE CITED

Albouy G, King BR, Maquet P, Doyon J. 2013. Hippocampus and striatum: Dynamics and interaction during acquisition and sleep-related motor sequence memory consolidation. Hippocampus 23:985–1004.

Alibali MW, Nathan MJ. 2012. Embodiment in mathematics teaching and learning: Evidence from learners' and teachers' gestures. J Learn Sci 21:247–286.

Anderson LW (Editor), Krathwohl DR (Editor), Airasian PW, Cruikshank KA, Mayer RE, Pintrich PR, Raths J, Wittrock MC. 2001. A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. 1st Ed. New York, NY: Longman. 352 p (abridged).

Anyanwu EG. 2014. Anatomy adventure: A board game for enhancing understanding of anatomy. Anat Sci Educ 7:153–160.

Azer SA, AlEshaiwi SM, AlGrain HA, AlKhelaif RA. 2012. Nervous system examination on YouTube. BMC Med Educ 12:126–133.

Barsalou LW. 2008. Grounded cognition. Annu Rev Psychol 59:617–645.

Bolek B. 2006. Facing cranial nerve assessment. Am Nurse Today 1:21–22.

Bromfield LJ. 2008. Cranial Nerve Boogie. In: Groovin' in the Hippocampus: Songs to Learn Anatomy and Physiology by. (CD Album). Spring Hill, TN: Clockwise Records. 4:32 min.

Caramazza A, Anzellotti S, Strnad L, Lingnau A. 2014. Embodied cognition and mirror neurons: A critical assessment. Annu Rev Neurosci 37:1–15.

Cartmill EA, Beilock S, Goldin-Meadow S. 2012. A word in the hand: Action, gesture and mental representation in humans and non-human primates. Phil Trans R Soc B 367:129–143.

Cobb WM. 1972. Facial mimetics as cranial nerve mnemonics. J Natl Med Assoc 64:385–396.

Cook SW, Yip TK, Goldin-Meadow S. 2012. Gestures, but not meaningless movements, lighten working memory load when explaining math. Lang Cognit Process 27:594–610.

Craig S, Tait N, Boers D, McAndrew D. 2010. Review of anatomy education in Australian and New Zealand medical schools. ANZ J Surg 80:212–216.

Dickson KA, Stephens BW. 2014. Engaging large and diverse cohorts of bioscience students in lectures using kinesthetic active learning. Int J Innovat Sci Math Educ 22:52–61.

Drake RL, Pawlina W. 2014. Multimodal education in anatomy: The perfect opportunity. Anat Sci Educ 7:1–2.

Goldin-Meadow S. 2011. Learning through gesture. Wiley Interdiscip Rev Cogn Sci 2:595–607.

Ionescu T, Vasc D. 2014. Embodied cognition: Challenges for psychology and education. Proc Soc Behav Sci 128:275–280.

Johnson TR, Lyons R, Chuah JH, Kopper R, Lok BC, Cendan JC. 2013. Optimal learning in a virtual patient simulation of cranial nerve palsies: The interaction between social learning context and student aptitude. Med Teach 35: e899–e907.

Jones AG, Jasperson J, Gusa D. 2000. Cranial nerve wheel of competencies. J Contin Educ Nurs 31:152–154.

Kooloos JG, Schepens-Franke AN, Bergman EM, Donders RA, Vorstenbosch MA. 2014. Anatomical knowledge gain through a clay-modeling exercise compared to live and video observations. Anat Sci Educ 7:420–429.

Macken L, Ginns P. 2014. Pointing and tracing gestures may enhance anatomy and physiology learning. Med Teach 36:596–601.

McMenamin PG. 2008. Body painting as a tool in clinical anatomy teaching. Anat Sci Educ 1:139–144.

Miller CJ, Metz MJ. 2014. A comparison of professional-level faculty and student perceptions of active learning: Its current use, effectiveness, and barriers. Adv Physiol Educ 38:246–252.

Nayak SB. 2006. The blanket method: A novel method of teaching peritoneal relations of female reproductive organs. Adv Physiol Educ 30:95–96.

Novack MA, Congdon EL, Hemani-Lopez N, Goldin-Meadow S. 2014. From action to abstraction: Using the hands to learn math. Psychol Sci 25:903–910.

Nowinski WL, Johnson A, Chua BC, Nowinska NG. 2012. Three-dimensional interactive and stereotactic atlas of the cranial nerves and their nuclei correlated with surface neuroanatomy, vasculature and magnetic resonance imaging. J Neurosci Meth 206:205–216.

Oh CS, Won HS, Kim KJ, Jang DS. 2011. "Digit anatomy": A new technique for learning anatomy using motor memory. Anat Sci Educ 4:132–141.

Richardson-Hatcher A, Hazzard M, Ramirez-Yanez G. 2014. The cranial nerve skywalk: A 3D tutorial of cranial nerves in a virtual platform. Anat Sci Educ 7:469–478.

Rizzolatti G, Sinigaglia C. 2010. The functional role of the parieto-frontal mirror circuit: Interpretations and misinterpretations. Nat Rev Neurosci 11:264–274.

Roth WM. 2001. Gestures: Their role in teaching and learning. Rev Educ Res 71:365–392.

Serrat MA, Dom AM, Buchanan JT, Williams AR, Efaw ML, Richardson LL. 2014. Independent learning modules enhance student performance and understanding of anatomy. Anat Sci Educ 7:406–416.

Shoval E. 2011. Using mindful movement in cooperative learning while learning about angles. Instr Sci 39:453–466.

Skinder-Meredith AE. 2010. Innovative activities for teaching anatomy of speech production. Anat Sci Educ 3:234–243.

Sugand K, Abrahams P, Khurana A. 2010. The anatomy of anatomy: A review for its modernization. Anat Sci Educ 3:83–93.

Tangalakis K, Hughes K, Brown C, Dickson K. 2014. The use of explicit teaching strategies for academic staff and students in bioscience foundation subjects. Int J Innovat Sci Math Educ 22:42–51.

Terrell M. 2006. Anatomy of learning: Instructional design principles for the anatomical sciences. Anat Rec 289B:252–260.

van Merriënboer JJ, Sweller J. 2010. Cognitive load theory in health professional education: Design principles and strategies. Med Educ 44:85–93.

Williams T. 2009. The Cranial Nerves. YouTube, LLC., San Bruno, CA. 2:29 min. URL: http://www.youtube.com/watch?v=ncs1EKJa648 [accessed 31 October 2014].

Xu X, Ke F. 2014. From psychomotor to "motorpsycho": Learning through gestures with body sensory technologies. Educ Tech Res Dev 62:711–741.

Yeung JC, Fung K, Wilson TD. 2011. Development of a computer-assisted cranial nerve simulation from the visible human dataset. Anat Sci Educ 4:92–97.

Yeung JC, Fung K, Wilson TD. 2012. Prospective evaluation of a web-based three-dimensional cranial nerve simulation. Otolaryngol Head Neck Surg 41: 426–436.

Zhang N, He X. 2010. Understanding the extraocular muscles and oculomotor, trochlear, and abducens nerves through a simulation in physical examination training. J Chiropr Educ 24:153–158.

Zumwalt AC, Lufler RS, Monteiro J, Shaffer K. 2010. Building the body: Active learning laboratories that emphasize practical aspects of anatomy and integration with radiology. Anat Sci Educ 3:134–140.