Using Wearable Sensor Badges to Improve Scholastic Performance

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Abstract
An experiment using wearable sensor badges showed that there was a strong correlation between students' physical behaviors and their scholastic performance. For example, students whose bodily movements were in harmony with those of their classmates during class and students with more face-to-face interaction during break times had better scholastic performance. These results indicate that it may be possible to improve scholastic performance by changing student behaviors, as measured using wearable sensor badges.

Author Keywords
Wearable sensor badge, face-to-face communication, physical behavior, scholastic performance.

ACM Classification Keywords
H.5.3 Information Interfaces and Presentation (e.g., HCI): Group and Organization Interfaces; K.3.1 Computers and Education: Computer Uses in Education.

Introduction
Children's education is of great interest worldwide because it directly affects the future of each country. Previous studies have reported that a student's scholastic performance is determined mainly by his or her family background [1]. In contrast, the controllable

factors in the school environment related to scholastic performance have not been sufficiently identified [3].

Progress in wearable sensor technologies has opened up new ways of studying complex human behaviors. Recent studies using wearable sensors have revealed, for example, that there is a significant correlation between employee physical behaviors, such as bodily movements and face-to-face interactions, and employee performance [4,5].

In the study reported here, we hypothesized that the bodily movements and face-to-face interactions of students and teachers in a school affect scholastic performance. We had fifth and sixth grade students and their teachers at entrance exam preparatory schools wear sensor badges to enable us to examine the relationship between their physical behaviors and scholastic performance.

Experiment

The badge-shaped wearable sensors (Fig. 1 (a)) we developed are for use in measuring physical behaviors. Data on the wearer's physical movements are captured by a three-axis MEMS (micro electro mechanical system) acceleration sensor and are used to detect individual activities such as keyboard typing, conversation with gestures, and walking. Six IrDA (infrared data association) transceivers on the front of the badge and facing different angles are used to detect face-to-face events. They can transmit and receive signals up to a distance of 3 m within a 15° cone. Two face 15° leftward horizontally, two face 15° rightward horizontally, and the other two face forward and 30° downward. With this alignment, the overall detection range is 60° horizontally and vertically, which should cover virtually any face-to-face interaction in a school environment. The transceivers are sequentially powered on and off to reduce power consumption. By using user IDs linked to each badge, information can be obtained about who met whom, when, and for how long. The captured data are stored in built-in 32-MB flash memory and offloaded for database transfer while the badge is in the charging cradle overnight. The badge is light and small enough to be hung from a child's neck during school hours (86 × 54 × 7 mm, 34 g, Fig. 1 (b)). The battery lasts about 24 hours between charges.

We had 82 students and 21 teachers at two schools wear sensor badges for 57 days (from 7 Sep. to 2 Nov. 2012) to collect data for use in measuring their behaviors. They met in small classes (usually 5 or 6 students with a maximum of 12 or 13). Most classes were in one of four subjects: mathematics, language, science, and social studies. We targeted 31 classes. All of the classes lasted 90 minutes. We obtained the standard scores of the targeted students on the monthly achievement tests conducted during our experimental period.

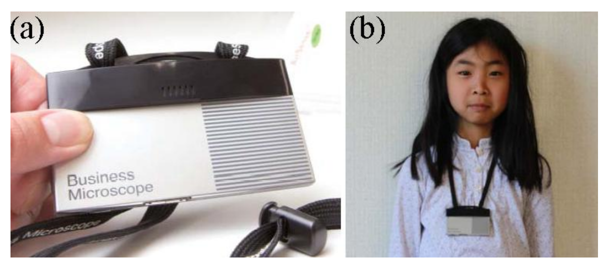

Figure 1. (a) Sensor badge and (b) child wearing it.

Results

Our analyses revealed that not only behaviors during class but also those during breaks correlated well with scholastic performance.

Synchronization with Classmates during Class

The badge wearer's activity level was judged to be in one of two states, active or non-active, every minute on the basis of the zero-crossing count of acceleration, defined as the number of times the acceleration signal crossed the zero-level per unit time. The activity level for a minute during which the zero-crossing count was greater than the threshold (set to the average of all the students' zero-crossing count across all classes; ~1.5 Hz) was judged to be in the active state; otherwise it was judged to be in the non-active state.

We defined a measure, U_{Class}, to represent the degree of cohesiveness of the class members: $U_{Class} \equiv \frac{1}{T}\sum_{t=1}^{T}\left[\frac{\max\left(n_{\text{active}}^{t}, n_{\text{non-active}}^{t}\right)}{N_{Class}}\right]$, where T is the total minutes the class was in session during our experimental period, N_{Class} is the total number of students in the class, and n_{active}^{t} and $n_{\text{non-active}}^{t}$ are the number of students in the class who were judged active and non-active at t, respectively. U_{Class} takes a value from 0.5 to 1.0.

We calculated U_{Class} for all 31 targeted classes and calculated its correlation with the class scores, z_{Class} (the average of the student scores for each class). We found that there was a significant correlation between them ($R = 0.41$, $p < 0.02$). This indicates that, if the students in a class behaved actively or quietly in a synchronized way, they got higher scores on average. In contrast, if each student behaved independently, the students got lower scores on average.

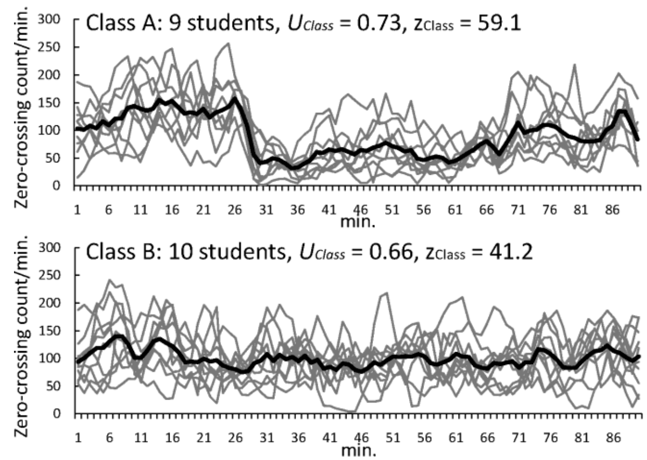

Figure 2. Synchronization of bodily movements of classmates.

An example of the acceleration signals measured for students during two class sessions (thin grey lines) and the average acceleration signals (bold black lines) are shown in Fig. 2. The average wave was dynamic for Class A and mostly flat for Class B, indicating that students in Class A, which had a higher average score, behaved in a synchronized manner whereas those in Class B, which had a lower average score, behaved in an independent manner.

Face-to-Face Interactions during Break Time

An example face-to-face network for break times is shown in Fig. 3. It represents face-to-face interactions among students and teachers per day averaged over our experimental period. The links were drawn if there was a face-to-face event between two people for a length of time exceeding a predefined threshold. The network diagram was drawn using the spring model, in which nodes with more links are located closer together

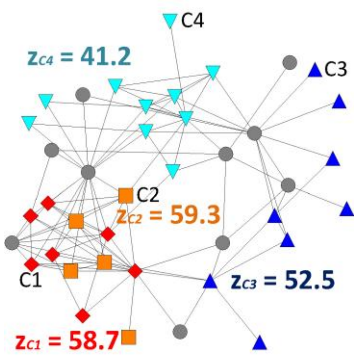

Figure 3. Face-to-face network in break time.

while those with fewer links are located further apart. Figure 3 presents the results for four mathematics classes identified as C1 to C4. It clearly shows that the members of the two classes with higher class scores (C1 and C2) had more links, indicating more interactions between them. In contrast, the members of the two classes with lower scores (C3 and C4) had fewer links, indicating fewer interactions between them.

Two indices, degree and clustering coefficient, were used to evaluate the activeness of the mutual face-to-face interaction. Degree k_i of node i was defined as the number of links connected to the node and represents the number of people with whom a student or teacher met. The clustering coefficient of node i was defined as $C_i=2e_i/k_i(k_i-1)$, where k_i and e_i stand for the number of nodes connected to node i and the number of links between them, respectively. This coefficient represents the density of the triangles formed by three nodes and the links between them. We calculated these indices for each class as the average for all the class members. We found that these indices correlated significantly with the class scores (degree: $R = 0.44$, $p < 0.02$; clustering coefficient: $R = 0.57$, $p < 0.001$). This indicates that classes with higher scores were composed of members who met more with other class members and who communicated more with each other during their breaks.

Discussion

We found that the performance of a class whose members behaved in a synchronized manner was better than that of another class whose members behaved in an independent manner. This finding indicates that a student's physical behavioral adaptation to those around him or her could improve his or her scholastic performance. It could also explain the peer effect phenomenon [2].

Our results also showed that the activeness of the face-to-face communication among class members during break times correlated well with performance. This is consistent with results obtained in various business fields [4,5] and could reflect a fundamental mechanism of human behavior and performance.

In short, it may be possible to improve scholastic performance by changing the physical behaviors of students and teachers, something that could be done by a school. The question of whether behavior affects performance or performance affects behavior is left for future work. We plan to conduct a long-term field study at entrance exam preparatory schools to evaluate the effect on scholastic performance of changing the behaviors of students and teachers, as measured continuously and quantitatively using our sensor badges.

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