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Multiple-microswitch technology to foster adaptive behavior in a man with acquired brain injury and pervasive/multiple disabilities

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Abstract

This study extends the use of microswitch technology for a man with acquired brain injury and pervasive/multiple disabilities, who had previously been involved in microswitch-mediated programs aimed at promoting adaptive behavior (i.e., object manipulation and head upright).
The objectives of this study were (a) to restore the adaptive level obtained in previous programs, but with the use of a more elaborate object manipulation response, (b) extend the adaptive behavior so as to include the presence of eyes open, and (c) establish a new form of practically useful adaptive response, namely, independent drinking.
The results showed that the participant improved his adaptive behavior to a level at which (a) virtually all object manipulation responses occurred in combination with head upright and eyes open, (b) the time with head upright and eyes open covered nearly the entire duration of the sessions, and (c) the drinking responses were largely consistent. The implications of the findings are discussed.

Keywords: Microswitches, Adaptive behavior, Multiple disabilities

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1. Introduction

Persons with pervasive/multiple disabilities, regardless of whether these are secondary to congenital encephalopathy or acquired brain injury, are generally characterized by limited adaptive behavior (Holburn, Nguyen, & Vietze, 2004; Mechling, 2006; Harries, Guscia, Nettelbeck, & Kirby, 2009; Lancioni, Bellini, Oliva, Singh, O'Reilly, & Sigafoos, 2010). They may show minimal or no interaction with objects and inappropriate postures with negative implications on a personal level (i.e., in terms of input reduction and physical deterioration) as well as socially (i.e., in terms of withdrawal with reduced levels of positive attention and interaction from others) (Lancioni, Singh, O'Reilly, Sigafoos, Oliva, Gatti *et al.,* 2008; Moir, 2010; Lancioni, O'Reilly, Singh, D'Amico, Ricci, & Buonocunto, 2011).

An improvement in adaptive behavior cannot really be expected if these persons are left to their own means and the resulting behavior does not acquire any specific meaning for them (Petry & Maes, 2007; Lancioni, O'Reilly *et al.,* 2008). Efforts to make the behavior meaningful may require the use of specific feedback/stimulation contingent on its occurrence; that is, contingent on the specific aspects of it (responses) that need to be motivated (Kazdin, 2001; Catania, 2007; Lancioni, Singh, O'Reilly, & Sigafoos, 2011). A valid support for the realization of those efforts may be represented by the availability of assistive technology (Lancioni, O'Reilly *et al.,* 2008; Chantry & Dunford, 2010; Borg, Larson, & Ostegren, 2011; Lancioni, Singh *et al.,* 2011).

Assistive technology could involve (a) microswitches to monitor the person's behavior (i.e., the responses targeted for feedback/stimulation intervention), (b) a microprocessor-based control system that records such behavior and activates brief periods of preferred stimulation contingent on the responses targeted, and (c) stimulus sources activated by the control system in relation to those responses (i.e., as mentioned above) (Holburn *et al.,* 2004; Mechling, 2006; Lancioni, O'-Reilly *et al.,* 2008; Lancioni, Bosco, Olivetti Belardinelli, Singh, O'Reilly, & Sigafoos, 2010). The aforementioned technology would be expected to be accurate in monitoring the person's behavior/responses, rapid and reliable in providing stimulation contingent on the occurrence of those responses, and effective in fostering the person's motivation to be active and accordingly increase his or her level of response (Lancioni, O'Reilly *et al.,* 2008, 2011; Moir, 2010).

This study aimed to extend the use of microswitch technology for a man with acquired brain injury and pervasive disabilities brain injury and other pervasive disabilities, who had previously (successfully) been involved in microswitch-mediated programs aimed at promoting adaptive behavior (i.e., object manipulation and head upright) (Lancioni *et al.,* 2011).

The programs had been temporarily interrupted due to the participant's health problems. The specific objectives of this study were (a) to restore the adaptive level obtained in previous programs, but with the use of a more elaborate object manipulation response, (b) extend the adaptive behavior so as to include the presence of eyes open, and (c) establish a new form of practically useful adaptive response, namely, independent drinking.

2. Method

2.1. Participant and setting

The participant was a man of 34 years of age who had suffered traumatic brain injury and coma following a work accident. His recovery from the coma included a long period in a vegetative state, which then changed into a minimally conscious state. At the time of this study, his total score on the Coma Recovery Scale-Revised (Kalmar & Giacino, 2005; Lombardi, Gatta, Sacco, Muratori, & Carolei, 2007) was 13, with partial scores of 1 on the oromotor/verbal and communication subscales, 2 on the arousal, visual and auditory subscales, and 5 on the motor subscale. His condition was characterized by severe visual impairment due to optic atrophy, hemiplegia with reduced trunk control, epilepsy that was partially controlled by medication, lack of speech, and absence of sphincteric control. He spent a large part of his time sitting in a wheelchair, in which he tended to be passive, dropping his head forward and closing his left eye or both eyes. Recent microswitch-based programs had been directed at promoting his object manipulation and head control (i.e., his ability to keep his head in an upright position rather than dropping it forward). The results had been positive but the programs had been temporarily interrupted due to the participant's health problems (see above). His family was eager to resume those programs and expand their use to help the participant keep his eyes open (i.e., countering his tendency to have one or both of them closed) and also drink independently (i.e., carrying out a response that was largely functional and needed). His family had also signed a formal consent for his participation in the study, which had been approved by a scientific and ethics committee.

2.2. Adaptive responses, technology, and stimuli

The adaptive responses included object manipulation, head upright/control, eyes open, and drinking via a special straw. Object manipulation responses consisted of taking common (ball- or pipe-like) objects from a container in front of him and placing them inside a box above it, (i.e., of performing simple

/ordinary object relocation actions). Head upright consisted of keeping the head in a fairly vertical position (i.e., deviating less than 35° from an ideal straight line). Eyes open consisted of keeping the eyelids open except for periods of less than 2 s (i.e., periods required for spontaneous blinking). Drinking from a straw involved drawing water from a small bottle fitted with the straw. The technology included microswitches for monitoring the responses, a microprocessor-based control system, and stimuli. The microswitches included (a) optic sensors inside the box in which the objects were to be placed (i.e., for object manipulation), (b) tilt devices on the arms of an eyeglasses' frame the participant wore (i.e., for head upright), (c) optic sensors on the left corner of the eyeglasses' frame close to (in front of) the participant's left eye (i.e., for eyes open), and (d) an optic sensor fixed at the intersection between the small bottle with water and the straw positioned to the left of the participant's face (i.e., for drinking). The microswitches were connected to the microprocessor-based control system that served for recording the responses (and additional information; see below) and activating the stimuli programmed for them during the intervention phases of the study (see below).

The stimuli used in the study had been previously selected through preference screening procedures (Lancioni, O'Reilly *et al.,* 2011). At the start of this study, one or two 10-s clips of some of the stimuli available were presented about five non-consecutive times to determine whether they were still producing positive reactions (i.e., alerting, orienting or smiling) in more than 50% of the presentations and thus could continue to be used. The final pool of stimuli included a variety of songs, vibratory inputs, as well as recordings of familiar, joyful voices talking to the participant. During the study, the presentation of these stimuli contingent on adaptive responses (i.e., for a scheduled period of 10 s) was followed by two- or three-word verbal encouragements about one third of the times. Those encouragements were thought to enhance concentration and positive responding (Lancioni, O'Reilly *et al.,* 2011).

2.3. Experimental conditions

Sessions lasted 5 min and were carried out three to 10 times a day, depending on the participant's availability. Measures recorded during the sessions concerned the (a) frequency of object manipulation responses, (b) frequency of those object manipulation responses occurred together with head upright, (c) frequency of those object manipulation responses occurred together with head upright and eyes open, (d) session time with head upright, (e) session time with eyes open, and (f) frequency of drinking responses. The measures were recorded through the microprocessor-based control system. Responses occurred with the help of prompting from the research assistant (see below) were

subtracted from the session total. Interrater agreement on recording the instances of response prompting was assessed in 55 sessions by having two research assistants record them simultaneously. Agreement, with the two assistants reporting the same numbers of response prompting, which could also be scored zero, occurred in all but one of the sessions.
The part of the study involving object manipulation, head upright, and eyes open was carried out according to an $ABB^1B^2AB^2$ design (Barlow, Nock, & Hersen, 2009). The A represented baseline conditions, the B intervention focused on object manipulation, the B^1 intervention focused on object manipulation together with head upright, and the B^2 intervention focused on object manipulation together with head upright and eyes open. The part of the study that involved drinking was carried out parallel to the last B^2 of the previous sequence according to a withdrawal (CDCD) design (Barlow *et al.,* 2009), in which C and D were used to identify the baseline and intervention phases (discriminating them from those of the previous sequence).

2.3.1. Baseline (A) phases. During the initial baseline (A) phase, the microprocessor-based control system and microswitches for object manipulation, head upright, and eyes open were available. However, no stimulation occurred in relation to the responses. Response prompting on object manipulation (i.e., verbal and physical guidance to take an object and place it in the box) occurred prior to the start of each session and eventually one or two times during the session if no independent responding occurred. Recording concerned all measures except drinking (see above). During the second baseline (A) phase, which was carried out between the two intervention (B^2) phases (see below), conditions differed in that the participant received verbal and physical prompting for object manipulation with head upright and eyes open before the start of the sessions. Prompting for head upright and eyes open consisted of verbal reminders and finger tapping on the participant's forehead or gentle lifting of the participant's eyelid(s).

2.3.2. Intervention (B) phase. During the intervention (B) phase, conditions were as during the first baseline (A) phase, except that object manipulation responses were followed by 10 s of preferred stimulation. A new response was recorded only if it occurred when the stimulation for the previous one had ended (Lancioni, O'Reilly *et al.,* 2008).

2.3.3. Intervention (B1) phase. During the intervention (B^1) phase, conditions were as in the B phase, except that object manipulation responses were followed by preferred stimulation only if they were accompanied by head upright. The B^1 phase was introduced by one practice session, in which the research assistant ensured through prompting (see above) that the two responses would occur together.

If head upright was not maintained for the entire 10-s period scheduled for the stimulation, this was interrupted prematurely.

2.3.4. Intervention (B^2) phases. During the intervention (B^2) phases, conditions were as in the B^1 phase, except that object manipulation responses with head upright were followed by preferred stimulation only if they also involved eyes open. The first B^2 phase was introduced by 12 practice sessions, in which the research assistant used prompting (see above) to ensure the presence of eyes open together with object manipulation and head upright. The stimulation following object manipulation responses accompanied by head upright and eyes open would last the 10 s scheduled only if the head upright and eyes open were maintained during the entire period. Otherwise, the stimulation was interrupted prematurely.

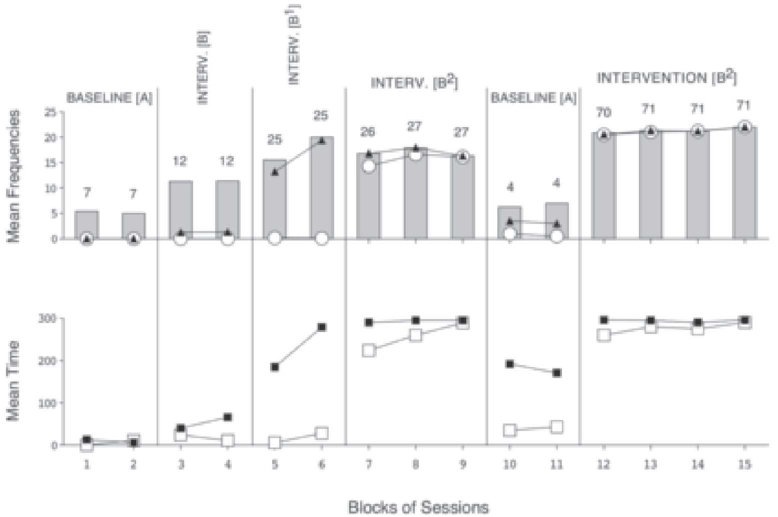
2.3.5. Baseline (C) phases. During the baseline (C) phases, the microprocessor-based control system and microswitch for drinking were available, but no stimulation occurred for drinking responses. The participant was prompted (i.e., verbally and physically guided to mouth the straw so that he could make a brief drinking movement/response) prior to the start of each session and eventually three or four more times during the session if no independent drinking responses occurred.

2.3.6. Intervention (D) phases. During the intervention (D) phases, conditions were as during the previous baseline (C) phases except that drinking responses were followed by 10 s of preferred stimulation. The first D phase was introduced by six practice sessions, in which the research assistant provided several prompting instances to help the participant experience multiple drinking-stimulation occasions.

3. Results

The gray bars of the upper panel of Figure 1 show the mean frequencies of object manipulation responses over blocks of sessions. The number of sessions included in each block is indicated by the numeral above it. The black triangles and empty circles connected to the bars indicate the mean frequencies of those object manipulation responses which were combined with head upright (triangles) or with both head upright and eyes open (circles), over the same blocks of sessions. The black and empty squares of the lower panel of Figure 1 show the mean session time (in seconds) with head upright and eyes open, respectively, over the aforementioned blocks of sessions.

Figure 1- *The gray bars of the upper panel of Figure 1 show the mean frequencies of object manipulation responses over blocks of sessions. The number of sessions included in each block is indicated by the numeral above it. The black triangles and empty circles connected to the bars indicate the mean frequencies of those object manipulation responses which were combined with head upright (triangles) or with head upright and eyes open (circles), over the same blocks of sessions. The black and empty squares of the lower panel show the mean session time (in seconds) with head upright and eyes open, respectively, over the aforementioned blocks of sessions.*



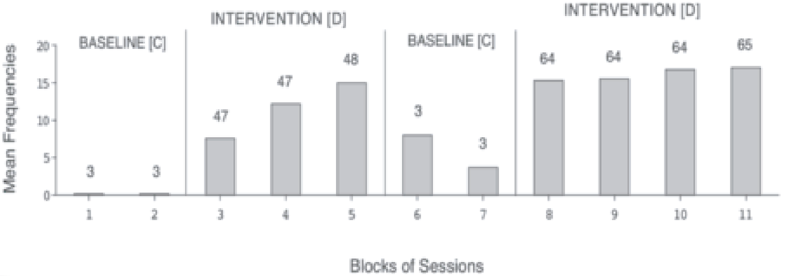
During the first baseline (A) phase (including 14 sessions), the participant had a mean of about five object manipulation responses per session. None of these object manipulation responses was combined with head upright or head upright and eyes open (see the black triangles and empty circles in the first/left section of the upper panel of Figure 1). During the intervention (B) phase (including 24 sessions), the mean frequency of object manipulation responses was about 11 per session. About one of those manipulation responses was combined with head upright, but none of them involved both head upright and eyes open (see the black triangles and empty circles in the second section, from the left, of the upper panel of Figure 1). During the intervention (B^1) phase (including 50 sessions), the mean frequency of object manipulation responses was above 15 per session. Most of these responses were combined with head upright, but virtually none of them included both head upright and eyes open (see the third section of the upper panel of Figure 1). During the first intervention (B^2) phase (including 80 sessions), the mean frequency of object manipulation responses was above 15 per session. Virtually all of them were combined with head upright and, by the end of the phase, with head upright and eyes open as well (see the fourth section of the upper panel of Figure 1). During the second baseline (A) phase (including eight sessions), the mean frequency of object manipulation responses dropped. About half of them involved head upright while almost none was accompanied by head upright and eyes open (see the fifth

section of the upper panel of Figure 1).
During the second intervention (B^2) phase (including 283 sessions), the mean frequency of object manipulation responses was about 20 per session. Virtually all of them were combined with head upright and eyes open (see the last section of the upper panel of Figure 1).

The lower panel of Figure 1 shows that the mean session time with head upright and the mean session time with eyes open were very low during the initial baseline and, to a large extent, during the intervention (B) phase. The time with head upright increased to a mean of about 230 s per session during the B^1 phase. This time increased/consolidated during the B^2 phases, during which the mean time with eyes open also increased up to almost the entire duration of the session.

The bars of Figure 2 show the participant's mean frequencies of drinking responses over blocks of sessions. The number of sessions included in each block is indicated by the numeral above it. During the first baseline (C) phase (including six sessions), the mean frequency of responses per session was zero. During the first intervention (D) phase (including 142 sessions), the mean frequency of responses per session was about 11. The mean frequency dropped during the second baseline (C) phase (including six sessions) and increased again to above 15 per session during the second intervention (D) phase (including 257 sessions).

Figure 2 - *The bars show the participant's mean frequencies of drinking responses over blocks of sessions. The number of sessions included in each block is indicated by the numeral above it.*



4. Discussion

The results indicate that the participant improved his adaptive behavior to a point where (a) virtually all object manipulation responses occurred in combination with head upright and eyes open, (b) the time with head upright and eyes open covered nearly the entire duration of the sessions, and (c) the drinking responses increased to a largely consistent level.

A person's consolidation of object manipulation with head upright and eyes open can be seen as functional/instrumental for ensuring his or her positive engagement with the immediate environment, reducing his or her risks of physical deterioration, and improving his or her social image (Lancioni, Bellini *et al.,* 2010; Lancioni, Singh *et al.,* 2008, 2011). A person's acquisition of the drinking response can be seen as a basic learning step within the area of self-help skills, that is, an area that represents an important target for any education and rehabilitation program (Lim, Girl, & Quah, 2000; Kemp & Carter, 2005; Rai, 2008).

The approach pursued in this study to promote adaptive behavior relies on the view that such behavior needs to be meaningful for the person (i.e., the view that the person needs to have motivation to perform it) (Kazdin, 2001; Catania, 2007). Promoting a person's motivation (through specific feedback/stimulation) produces an increase in his or her active role, a clear level of self-determination, and possibly a sense of pleasure in performing the target behavior/responses (Jumisko, Lexell, & Söderberg, 2009; McDougall, Evans, & Baldwin, 2010). Such a condition could also be expected to foster a positive perception (i.e., positive reactions) from caregivers and staff with beneficial effects on their interactions with the participant (Brown, Schalock, & Brown, 2009; Hostyn & Maes, 2009; Sunderland, Catalano, & Kendall, 2009; Narayan, Bruce, Bhandari, & Kolli, 2010; Shih, Shih, & Shih, 2011).

The technology in the form used in this study or in an advanced/upgraded form must be considered critical in developing and maintaining adaptive behavior in persons with pervasive multiple disabilities (Baker & Moon, 2008; Blain, McKeever, & Chau, 2010; Chantry & Dunford, 2010; Borg *et al.,* 2011; Lancioni, O'Reilly *et al.,* 2008, 2011). Indeed, the technology (a) would be fairly accurate in detecting responding, and rapid in providing stimulation contingent on its occurrence (i.e., thus ensuring the persons' motivation to respond independently of staff intervention), and (b) would allow repeated daily engagement periods at an affordable staff cost within rehabilitation and care centers (Nota, Ferrari, Soresi, & Wehmeyer, 2007; Carter, Owens, Trainor, Sun, & Swedeen, 2009; Lancioni *et al.,* 2011).

In conclusion, the data of this study underline the possibility of promoting adaptive behavior in persons with pervasive/multiple disabilities through the support of technology-aided programs involving multiple microswitches. New research efforts are needed to (a) extend the assessment of those programs (and microswitch devices) with other participants to verify the generality of the present findings, and (b) carry out a social validation assessment in order to determine staff and family members' opinions about the practicality/usability and implications of the reported programs (Kazdin, 2001; Kennedy, 2005; Callahan, Henson, & Cowan, 2008; Lancioni, O'Reilly *et al.,* 2011).

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