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A rehabilitation program based on music practice for patients with unilateral spatial neglect: a single-case study

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ABSTRACT

Two major limitations of unilateral spatial neglect (USN) rehabilitation methods are actually reported: a lack of long-term efficiency and a lack of generalization to daily life. The aim of our case study was to underline how a multisensory method—music practice—could avoid these limitations. Mrs BV suffered from a chronic severe USN. She had rehabilitation sessions of music practice over 8 weeks. An improvement of her USN was found on paper-pencil tests but also in daily activities. Benefits subsisted 4 months after rehabilitation. Music practice seemed to avoid the major limitations of USN rehabilitations and could represent a promising tool.

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Unilateral spatial neglect; rehabilitation; music practice

Introduction

Unilateral spatial neglect (USN) is characterized by a deficit of attention in the contralesional side of space (Posner, Walker, Friedrich, & Rafal, 1984). It occurs after a cerebral stroke most commonly of the right hemisphere (Bartolomeo, Thiebaut de Schotten, & Chica, 2012). USN is an important negative prognostic factor for functional recovery and of socio-professional reinsertion (Denes, Semenza, Stoppa, & Lis, 1982; Held, Pierrat Deseilligny, & Bussel, 1975). Therefore, rehabilitate USN is necessary for patients' outcome.

Although USN is described in many sensory modalities including hearing (De Renzi, Gentilini, & Barbieri, 1989; Pavani, Meneghello, & Làdavas, 2001), rehabilitation methods are mainly based on visual or tactile modalities and on motor abilities (for a review, see Luauté, Halligan, Rode, Rossetti, & Boisson, 2006). Very few rehabilitation programs are based on the auditory modality (for a review, see Guilbert, Clément, & Moroni, 2014). We therefore investigated an auditory rehabilitation strategy.

In our study, we focused on music practice as a method to rehabilitate USN. This practice is a multisensory method involving vision, hearing, and action, which is an additional asset because, on the one hand, motor retraining appears to show a significant effect on USN (Robertson & North 1992) and, on the other hand, previous studies have shown that listening to music can improve spatial attention in patients with USN (Chen, Tsai, Huang, & Lin, 2013; Soto et al., 2009; Tsai et al., 2013).

Only Bodak, Malhotra, Bernardi, Cocchini, and Stewart (2014) have investigated music practice as a way to rehabilitate patients with USN. This study underlined positive effects of music practice on spatial attention for two patients with chronic USN. However, this study presented some limitations: No ecological evaluation was included and no long-term evaluation was realized (only 1 week after the rehabilitation

program). Therefore, this study did not avoid the two major limitations of USN rehabilitations: a lack of long-term efficiency and a lack of generalization to daily life (Luauté et al., 2006). Our study aimed to counteract these two aspects by including long-term evaluations (at 2, 4, and 5 weeks and 4 months after the rehabilitation program) and implementing a daily activities questionnaire with the Catherine Bergego Scale (CBS) (Bergego et al., 1995).

Many studies have argued that pitches and space are closely linked and could have an impact on USN (for a review, see Guilbert et al., 2014). Cerebral areas, located in the intraparietal sulcus (IPS), are activated during tasks involving music pitch comparisons and during space perception tasks (Corbetta, Kincade, Lewis, Snyder, & Shulman, 2005; Foster & Zatorre, 2010). The IPS is hypo-activated during spatial attention orienting tasks in patients with USN (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000). Thus, close links exist between cerebral networks involved in spatial attention and in the cognitive processing of pitches. According to Lidji, Kolinsky, Lochy, and Morais (2007) and Rusconi, Kwan, Giodarno, Umiltà, and Butterworth (2006), the similar cerebral networks activities can be explained by the idea that pitches can be conceptualized as positions on a mental line oriented either vertically or horizontally (in the case of an explicit pitch comparison task with non-musicians). Ishihara et al. (2013) showed that listening to higher or lower pitches could modulate results on a line bisection task, both for healthy controls and for patients with USN. Musical scales involving the production of predictable successive pitches also help spatial attention orienting for patients with USN (Bernardi et al., 2015). All these studies suggest a specific impact of pitches on USN.

In order to specify which aspect of music is associated with the greatest benefit of rehabilitation in patients with USN, we

compared two different music practice programs: one based on pitches and the other based on rhythms. The first implies a linear representation of pitches, whereas the second does not. We also evaluated musical capacities in order to potentially link spatial attention evolution with an improvement in musical capacities. According to previous studies (Bernardi et al., 2015; Lidji et al., 2007; Rusconi et al., 2006), we expected the pitches program to be more efficient on USN signs than the rhythms program.

Methods

Patient

BV was a 52-year-old woman, working as an occupational therapist, who suffered from a hemorrhagic stroke of the right middle artery 20 months prior to baseline testing (cf Figure 1).

BV presented a chronic severe USN on the left side of space (cf initial evaluation in Table 1). No anosognosia was associated. She spontaneously spoke of her difficulties in everyday activities. She lived at home with her husband.

None of the many rehabilitation methods BV had previously used (visuospatial exploration retraining, eye patching, electric stimulations) had shown conclusive results. She had been included in a research program 8 months before our program. She received a combination of eye patching and visuospatial exploration retraining over 3 weeks. No improvement on two tasks was shown with this program (on a cancellation task and on a line bisection test). Moreover, she evaluated her USN at the same range before and after this program (12/30 with the CBS). Until now, she had not yet received another rehabilitation program. Her performance was stable and she still evaluated her USN at 13/30 with the CBS before starting this actual program. No spontaneous remission was expected with regard to the stability of these evaluations.

An audiogram revealed no auditory deficit. A left hemiplegia and a left homonymous lateral hemianopsia (HLH) were associated with her USN. Two binocular campimetric measures done 6 months before the beginning of the rehabilitation program and 5 weeks after the rehabilitation program (in Post 3) showed a stability of her left HLH (cf Figure 2). No difference was found between these two examinations: Her left HLH was stable.

BV had never had music training, had no specific interest in music, and reported almost never listened music.

Other than her USN, there was no known prior neurological, cognitive, or psychiatric disease. According to the Declaration of Helsinki (2013), BV gave a full consent to participate to this program.

Table 1. Results on the BEN (deficitary results in bold).

		Pre 2	Post 2
Bells test	Left omissions	6/15	2/15
	Total omissions	7/35	4/35
	Starting point	7th column	7th column
Figure copying		1/4	0/4
Clock drawing		0/2	0/2
Line bisection	5-cm lines	-2.5 mm	-2 mm
	20-cm lines	28 mm	28.25 mm^a
Overlapping figures	Left omissions	0/10	0/10
Reading	Left omissions	8/61	15/61
Writing	Margin	2.2 cm	1.3 cm

^aLine bisection was deficitary 4 weeks after the end of rehabilitation (Post 2) but was in the norms 2 and 5 weeks and 4 months after (Post 1, 2, and 4) (cf results part 2)

Rehabilitation programs

Two different programs were proposed: one based on the rhythms (percussion program—program A) and the other based on pitches (piano program—program B). We decided not to include another control rehabilitation program, because of time constraints. Moreover, the USN of this patient was stable and a previous rehabilitation (with eye patching and visual exploration retraining) failed to improve her USN symptomatology.

The material used was composed of 12 pads connected to an Alesis Trigger and a Mac computer with Logic Pro 9 software (cf Figure 3). During the percussions program, each pad corresponded to a percussion sound (each pad had a different timbre: drums, cymbals, toms, cf “acoustic drum kit” in Logic Pro 9). During the piano program, each pad corresponded to a piano note with a difference of a semitone between each pad (from C1 to B1, cf “Yamaha piano studio” in Logic Pro 9).

Each rehabilitation program was composed of six sessions of 30 min. Each session began with music scales: BV had to explore each pad of the keyboard from the far left pad to the far right pad, then from the far right pad to the far left pad (three times in a row). Then, she had to explore the pads alternating from the left to the right and from the right to the left (three times). The second part of the session corresponded to (1) listening to a sequence of four pads and (2) repeating this sequence. In the piano session, a simple sequence of four musical notes (four pads) had to be repeated. In the percussions sessions, a rhythmic sequence based on four pads had to be played. Each pad had a different rhythm (e.g., four 16th notes could be played on one pad, two 8th notes on another pad, and so on.). BV had to find pads of the sequence by ear; several trials were permitted to repeat the sequence. She could listen to each pad as many times as she desired. Piano sessions and percussions sessions were built with the same pattern: the same four pads were used during the first piano sequence and the first percussions

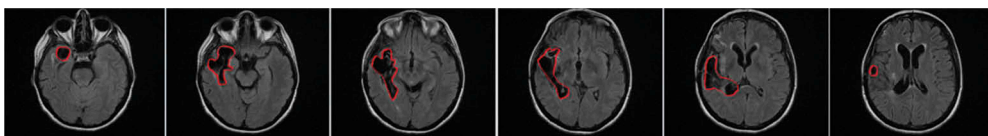


Figure 1. Lesion reconstruction plotted from magnetic resonance imaging acquisitions (T2 flair).

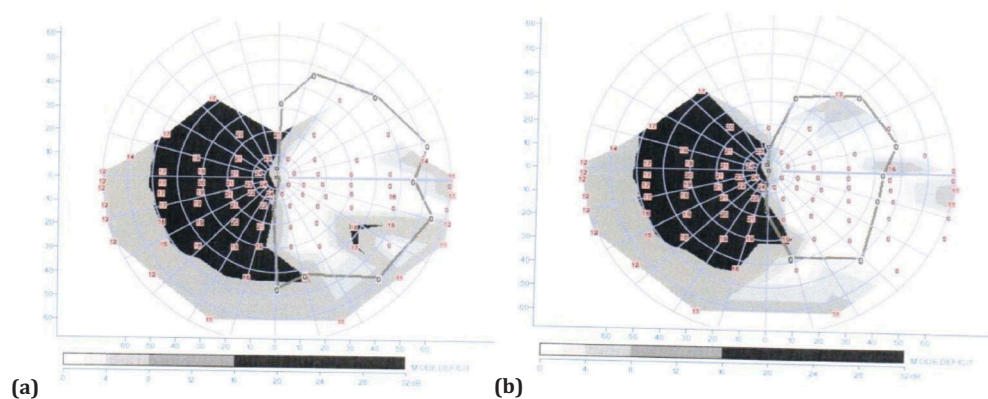


Figure 2. Binocular visual field: (a) 6 months before the beginning of the rehabilitation program and (b) 5 weeks after the end of the rehabilitation program (Post 3).



Figure 3. Rehabilitation material.

sequence, etc. Thus, the exploration of the device involved the same pads in both rehabilitation programs. During the piano sessions, the pad had to be found by ear by comparing pitches. In the percussions sessions, no pitch comparison was required to find the right pad as each pad had a specific timbre. BV had to reproduce the rhythm allocated to each pad. According to the patient, both programs were equally difficult and the time needed to repeat a pitch sequence or a rhythmic sequence was the same. When the sequence was correctly repeated, another sequence was proposed. Four sequences were used during each session. At the end of each session,

BV was free to play whatever she chose for 3 min. If she stopped during these 3 min, she was invited to play again. Her production was recorded in order to evaluate her exploration of the pads (called “free expression”).

Material to assess the efficiency of the programs

An experimenter, blind to the rehabilitation program, carried out the evaluation sessions (Pre 3, Percussions 1, Piano 1, Break, Piano 2, Percussions 2, Post 1 and Post 2) (cf [Figure 4](#)). The first complete evaluation (Pre 2) and a 4-month follow-up evaluation

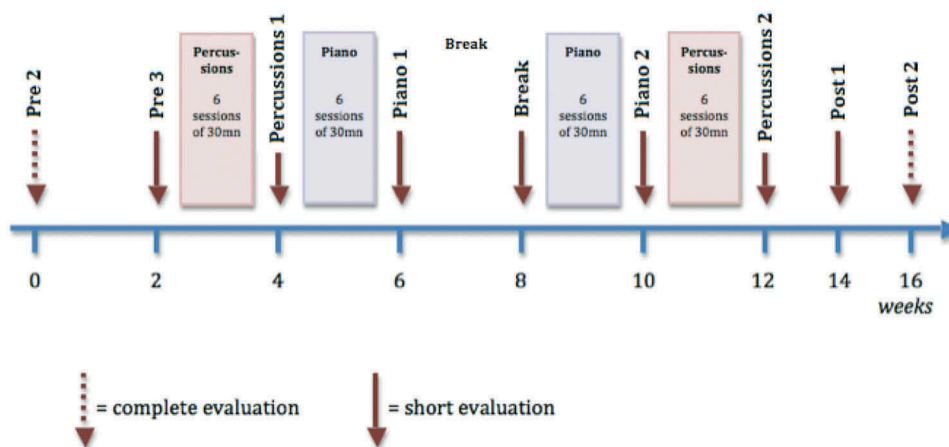


Figure 4. Rehabilitation procedure.

(Post 4) were carried out by the experimenter in charge of the rehabilitation. We also decided to add data from two other evaluations Pre 1 (2 months before the beginning of the program) and Post 3 (5 weeks after the end of the program), which were visits in a hospital service made by a third person.

As the evaluations Pre 1, Post 3, and Post 4 were routine visits, they are not reported in Figure 4 and were only composed of a line bisection test and a Bells test. A CBS was also carried out during Post 4.

Complete evaluations made 2 weeks before (Pre 2) and 4 weeks (Post 2) after the rehabilitation (cf Figure 4) are as follows:

- Battery of Evaluation of spatial Neglect (BEN) (Azouvi et al., 2006): the BEN consists of visual-motor tasks (Bells cancellation test, copy drawing, clock drawing, line bisection, writing) and perceptual tasks (overlapping figures test, reading).
- An auditory target-lateralization task (Guilbert, Clément, Martin, Feuillet, & Moroni, 2016).
- Two subtests of the Montreal Battery of Evaluation of Amusia (MBEA): the contour and the rhythm tests (Peretz, Champod, & Hyde, 2003) (only these two subtests, one based on pitches and the other on rhythms, were chosen because of time constraints).
- Sound frequency comparison test: the patient has to judge between two sounds which one is higher. A discrimination threshold was calculated, corresponding to the interval in cents between two pitches to which the patient answers correctly 75% of the time.

Short evaluations made between each program every 2 weeks (Pre 3, Percussions 1, Piano 1, Break, Piano 2, Percussions 2, and Post 1) (cf Figure 4) are as follows:

- Bells test, extracted for the BEN: On an A4 sheet of paper, the patient has to circle the 35 bells mixed with 280 distractors. Left, right, and total omissions and localization of the first detected bell were scored.
- Line bisection test, also extracted from the BEN: The patient is required to bisect eight lines (4 lines of 20 cm and 4 of 5 cm alternatively). Only 20-cm lines were taken into account in this study, as no difficulty was underlined for 5-cm lines. We measured rightward deviations from the center.
- CBS (Bergego et al., 1995): The patient has to answer to an auto-questionnaire composed of 10 items that correspond to common everyday situations with her husband's help. For each item, a 4-point scale is used, ranging from 0 (no neglect) to 3 (severe neglect). A total score on 30 was calculated.
- Sound frequency comparison test.

Moreover, scores were collected from the "free expression" produced at the end of each session. The production of the patient was recorded and we extracted the total number of hits on the pads. The percentages of hits on the extreme left pad (pad 1) and on the extreme right pad (pad 12) compared to the total hits were also calculated.

Procedure

Three weekly 30-min intervention sessions were implemented. The order of the two music programs was counterbalanced (AB-BA procedure) with a break of 2 weeks between this counterbalancing (cf Figure 4).

Operational hypotheses

Our two main aims were to explore whether music practice rehabilitation program would be an effective tool for USN rehabilitation and to identify which aspect of music is associated with the greatest benefit of rehabilitation. Thus, two different hypotheses were tested:

Our music practice-based program would ameliorate USN

We expected that our two music programs would have a beneficial effect on visual and auditory signs of USN and also on daily life. We hypothesized that we would see

- on complete evaluations, an improvement on all the tasks of the BEN and the auditory target-lateralization task between pretest (Pre 2) and posttest (Post 2).
- on short evaluations, a decrease of the left omissions on Bells test and of the rightward deviation on line bisection test and an improvement on the CBS over the sessions. We also expected that the benefits would persist (until evaluation point Post 4).
- on free expressions, an increase of the number of hits on the pads, which would indicate a better exploration of the pad display in its entirety, an increase in the use of the extreme left pad and a decrease in the use of the extreme right pad (suggesting a diminution of the right attentional anchoring).

Pitch practice would be more efficient than rhythm practice

According to Lidji et al. (2007), explicit comparisons of pitches could be more efficient on USN than rhythms comparisons. Furthermore, according to Bernardi et al. (2015), musical scales help attentional orienting. Therefore, we expected a better improvement in USN with the piano program than with the percussions program. We hypothesized that we would see:

- on complete evaluations, an improvement of correct answers in the subtest "contour" of the MBEA, which would suggest links between pitches and improvement of USN.
- on short evaluations, greater improvements on the Bells test (left omissions), on the line bisection test (rightward deviation), and on the CBS after the piano programs than after the percussions programs. We also expected an improvement of the discrimination threshold of the sound frequency comparison test after the piano programs.
- on free expressions, a better exploration of the pads (an increase in the number of hits, increase in the use of pad 1 and decrease in the use of pad 12) with piano programs than with percussions programs.

Analyses of results

Randomization tests (Todman & Dugard, 2001) were realized for the line bisection test, for the Bells test, and for the sound frequency comparison test. Comparisons were made between measures done before the rehabilitation program (Pre 1, 2, and 3) and after (Post 1, 2, and 3) to test the hypothesis 1. Comparisons were also made between scores after the piano programs (Piano 1 and 2) and after the percussions programs (Percussions 1 and 2) to test the hypothesis 2. *t*-Tests were used to analyze the results of the auditory target-lateralization task. An alpha level of 0.05 was adopted for all statistical analyses (one-tailed *p*-value).

Only descriptive analyses were realized for the BEN, the two subtests of the MBEA and the CBS, as data did not permit inferential statistics. A comparison was made between before and after the rehabilitation program. Descriptive analyses were also realized for free expressions over the sessions.

Results

Complete evaluations

BEN

Two weeks before the beginning of the rehabilitation program (Pre 2), BV showed many impaired scores compared to normative data in the Bells test, in the line bisection test, in the copy drawing, and in reading (cf Table 1). Four weeks after (Post 2), only two tests were failed: the line bisection test (20-cm lines) and reading. The line bisection test was only failed in Post 2 and not in Post 1, Post 3, or Post 4, which suggests an improvement in this test after the rehabilitation program (cf line bisection section). However, a decrease in performance in reading was observed: Reading was still difficult after the rehabilitation program. No difficulty was found again for the Bells test (except for the first column explored) or for the copy drawing.

Auditory target-lateralization task

No difficulty of lateralization in hearing was shown before the program: She was as fast to respond to left auditory targets as

Table 2. Results on the two subtests of the MBEA (deficitary results in bold).

	Pre 2	Post 2
Subtest 2 "Contour"	20/30	19/30
Subtest 4 "Rhythm"	19/30	25/30

to right auditory targets ($t(242) = -1.02$, $p = 0.15$, left targets: $M = 670$ ms, right targets: $M = 702$ ms). However, response times were impaired compared to healthy participants (cf Guilbert et al., 2016). No improvement was shown between Pre 2 and Post 2; the patient was slower after the program ($t(419) = 3.67$, $p < 0.001$, before: $M = 691$ ms; after: $M = 765$ ms). After the program, she was still as fast to answer to left targets in comparison to right targets ($t(247) = -0.13$, $p = 0.45$, left targets: $M = 763$ ms, right targets: $M = 767$ ms).

MBEA subtests

According to the two subtests of MBEA, before the rehabilitation program, BV could be categorized as an "amusic" patient for melodies and rhythms (Peretz et al., 2003) (cf Table 2). After the rehabilitation program, she still had an amusia for melodies, whereas she no longer had a rhythmic deficit: She showed an improvement for the cognitive processing of rhythms.

Short evaluations

Line bisection

A significant improvement was found in the line bisection scores after the program ($p = 0.012$) (cf Figure 5). Whereas BV had a main rightward deviation of about 30 mm before the program (Pre 1, 2, and 3), post-program she deviated by 13 mm on average (Post 1, 2, and 3).

The piano program seemed slightly more efficient than the percussions program in this task; however, only a statistical trend was observed ($p = 0.07$).

Four months after the end of the rehabilitation (Post 4), BV maintained, and even improved, the benefits with a rightward deviation of 5.75 mm.

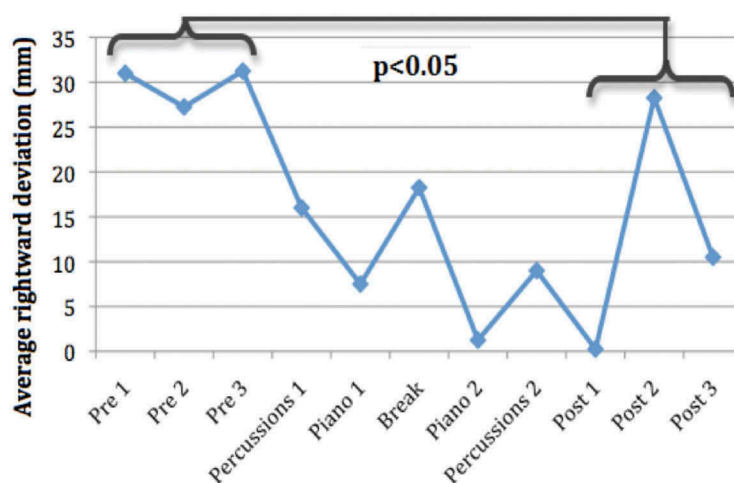


Figure 5. Average rightward deviation for the 20-cm lines on the line bisection test.

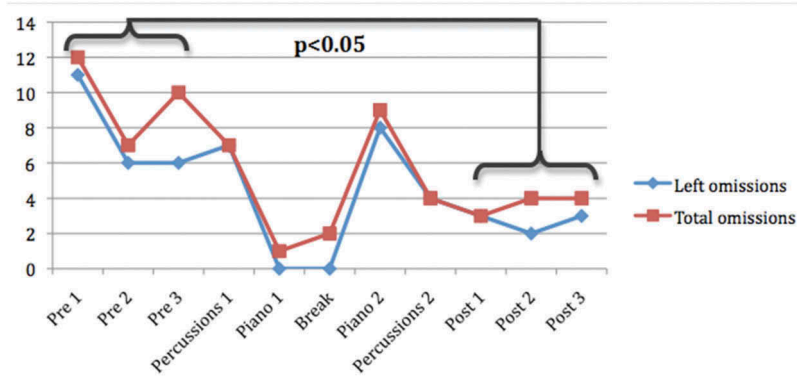


Figure 6. Number of left and total omissions for the Bells test.

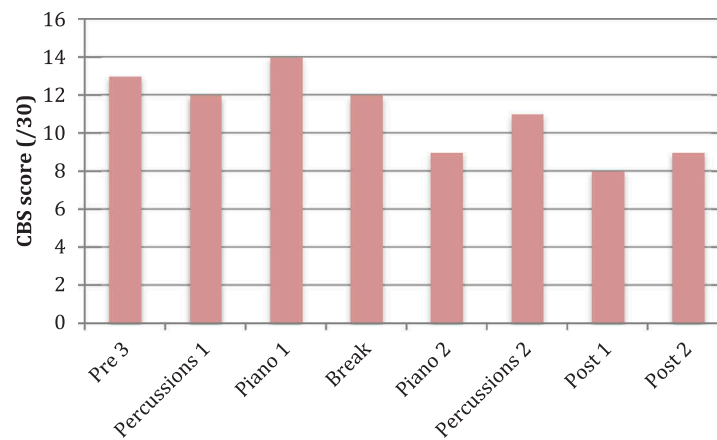


Figure 7. Scores in auto-evaluation on the Catherine Bergego Scale.

Bells test

An improvement was found on the Bells test for left-side omissions and total omissions over the sessions (cf Figure 6). After the second session based on piano (Piano 2), there was a high score of omissions. However, this was due to involuntary movements of her left arm during this test. Thus, it was not possible to compare the two programs. However, the first percussion program seemed to have no impact on this test (cf Percussions 1) contrary to the first piano program (cf Piano 1).

A significant improvement was found after the program ($p = 0.05$ for left-side omissions and for total omissions). Whereas BV forgot around 10 bells on average with around 8 left bells before the rehabilitation (Pre 1, 2, and 3), she only neglected 4 bells with 3 left bells on average after the rehabilitation (Post 1, 2, and 3).

Four months after the end of the program (Post 4), BV maintained her improvement on the Bells test with only two omissions (one on the left side and one on the right side of the sheet).

Auto-evaluation of USN (CBS)

BV evaluated her USN as moderate before the rehabilitation program (Pre 3: CBS score: 13/30), whereas she evaluated it as mild after the program (CBS scores: 8/30 in Post 1 and 9/30 in Post 2) (cf Figure 7). She noted differences in everyday life between before and after the rehabilitation program. While

she had often reported having difficulties to orient her gaze to the left side of space before the program, this difficulty was not reported after the program. She also noted improvements in her ability to dress, eat, and move in space. Her husband also reported these improvements with more autonomy in daily activities. Nevertheless, BV occasionally still had difficulties to find objects on the left side of space. At the end of the program, thanks to its benefits, she took up one of her favorite pastimes—woodworking—and showed considerable progresses but she was unable to do it before the rehabilitation program.

A score of 8/30 was still found 4 months after the end of the program (Post 4).

Sound frequency comparison test

No improvement was found for the sound frequency comparison between pre- and post-evaluations ($p = 0.44$), or over the sessions (cf Figure 8).

Free expressions

Number of hits

The number of hits during the free expression increased over the sessions (cf Figure 9). At the beginning of the program, BV hit around 150 pads, whereas at the end she hit approximately 300 pads in 3 min.

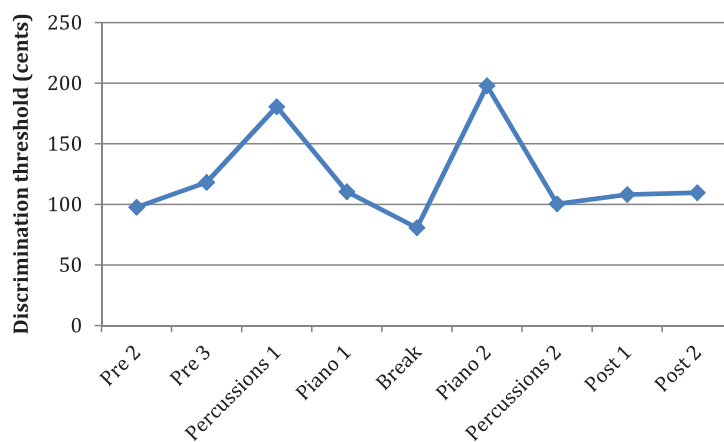


Figure 8. Results on the sound frequency comparison test.

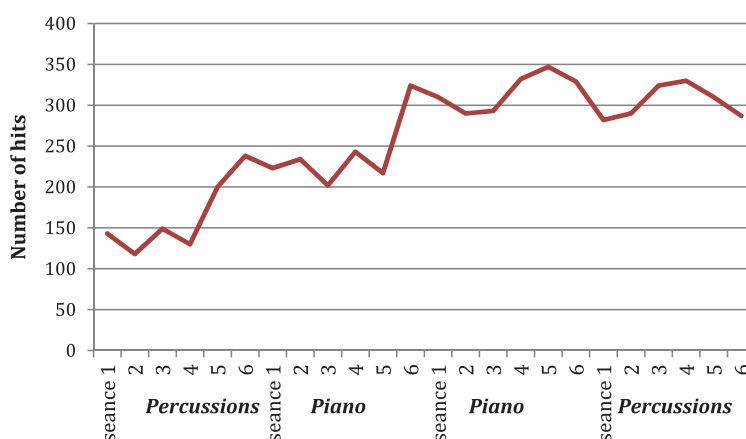


Figure 9. Number of hits during the free expression.

Left pad (pad 1) versus right pad (pad 12)

At the end of the first session, an over-utilization of the right pad (14% of the time) and an under-utilization of the left pad (4.9% of the time) were observed (cf Figure 10). This was not the case for the other sessions. Over the sessions, the two extreme pads of the device tended to be used equally. Moreover, during the latter sessions, the left pad was more

used (9% and 7% for the two last sessions) than the right pad (around 5% of the time).

Discussion

In this case study, our goals were to highlight a beneficial effect of our program based on musical practice on USN

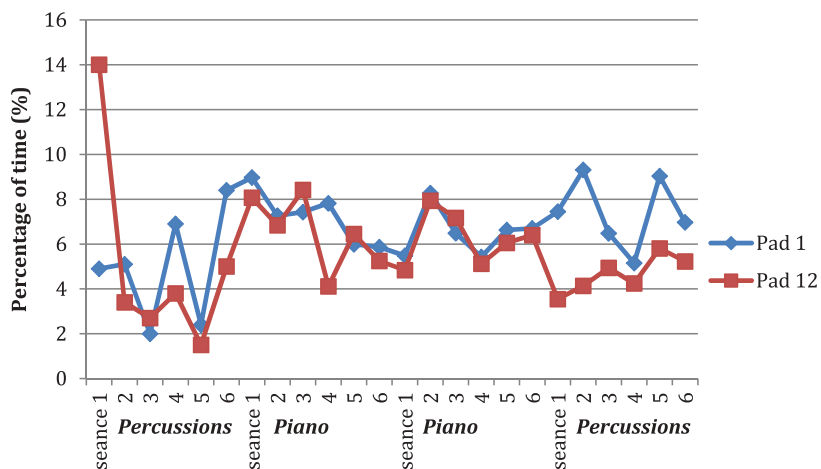


Figure 10. Percentage of hits allocated to the far left pad (pad 1) and the far right pad (pad 12).

syndrome and to identify which aspect of music could explain this improvement.

Efficiency of the music practice-based program

BV showed a decrease in intensity of her USN visual signs after the end of the rehabilitation. There was an improvement on the BEN, except on the reading task performance, which seemed to worsen between the two measures. There was also an improvement on the Bells test and line bisection scores between before and after the rehabilitation program. This recovery of her USN syndrome is not linked to a joint improvement of sustained attention (Robertson, Tegnér, Tham, Lo, & Nimmo-Smith, 1995). During the auditory target-lateralization task, BV seemed to show massive deficits in sustained attention with no asymmetrical difficulty: She was as slow to lateralize right targets as she was to left targets. No improvement was found after the rehabilitation program. On the contrary, the global performance decreased between before and after the rehabilitation, which suggests that our program had no benefit either on sustained attention or on speed of information processing. Our music program seemed to have a specific impact on spatial attention and not on other aspects of attention. However, it could be interesting to repeat this program with other patients and assessing more aspects of attention to investigate it further.

Over the sessions, during free expressions, we found an increase in the number of used pads and a better exploration of space, with a decreasing of the right side anchoring, which is the main attentional characteristic of patients with USN (Posner et al., 1984).

This improvement could not be linked to an evolution of the left HLH and could rather suggest a compensation of the USN.

Overall, we can state that, for this patient, our music practice-based program was more efficient than the previous program based on a combination of two other methods (eye patching and visual exploration retraining).

Piano versus percussions programs

No significant difference was found between our two musical programs of rehabilitation: Both seemed to have a beneficial effect on USN signs. This result is quite counter-intuitive according to our hypotheses (Lidji et al., 2007; Rusconi et al., 2006).

Concerning music abilities, no improvement for sound frequency comparison over the sessions and no improvement for the “contour” subtest of the MBEA were found. This means that no improvement in pitch perception was found. However, we found that BV’s capacities to compare rhythms improved. This is rather in support of the fact that rhythms could also have a positive effect on USN.

Our study did not find a specific effect of pitches on USN. Benefits could therefore be linked to more general effects on cognition linked to motivation and the emotions induced by music (for a review see Guilbert et al., 2014; Sarkarmo et al., 2008; Thompson, Schellenberg, & Husain, 2001). Indeed, BV was very enthusiastic and motivated by music sessions, which was

not the case for the previous rehabilitation methods she tried. This motivational hypothesis could potentially explain the improvement for the rhythm discrimination. However, a reiteration with more patients would be necessary to conclude on the impact of each musical program (pitch and rhythm) on USN, as a statistical trend was found for the line bisection test in favor of the piano program compared to the percussions program.

Another interesting contribution of this case study is that, although our patient could be qualified as severely amusic and had no real interest in music, she became very involved in the music rehabilitation program and also benefited from it. Similarly, Bernardi et al. (2015) found that amusic patients could benefit from musical scales. Therefore, amusia does not seem to be a contraindication to a music rehabilitation for patients with USN.

A real USN improvement or a test-retest effect?

One might wonder if the repetitions of the evaluations could have influenced our results. In our design, BV had 12 evaluations of the Bells test and 12 of the line bisection test in total. Could the improvement found on both tests be influenced by practice? Our evaluations were made only once every 2 weeks during the rehabilitation program. Thus, the time was quite long between two evaluations, compared to some other studies. For example, in Samuel et al.’s (2000) study, the Bells test and the line bisection test were used to assess the efficacy of their rehabilitation program on two patients, and were completed four times a week over 8 weeks. Despite this high frequency, no significant difference was found on the Bells test for their patients, which suggests that this test was not sensitive to repetitions. Moreover, Machner, Mah, Gorgoraptis, and Husain (2012) found high test-retest reliability for the Bells test, when repeated 5 days in a row: The Bells test was very stable on retesting. Thus, the Bells test is a very recommended measure for the longitudinal assessment of USN severity.

The test-retest reliability was lower for the line bisection test; patients with USN are characteristically variable in their response in line bisection tasks (Marshall & Halligan, 1989). However, Machner et al. (2012) provided “error-bands” in absolute test units. For the line bisection test, a deviation of more than 16 mm is most likely due to a change in USN severity than to test variability. Regarding our results, a difference of 25.5 mm was found between Pre 3 (just before the beginning of the program) and Post 4 (4 months after the program ended), which suggests a genuine USN improvement. Moreover, we observed a plateau at baseline in the line bisection test (Pre 1, Pre 2, and Pre 3), which implies that BV was in a chronic phase of USN, and an improvement only when the rehabilitation was implemented. In light of all these elements, our results suggest a real improvement of USN severity for BV following the music program.

Conclusion

To compare with Bodak et al. (2014), our music practice-based program had long-term effects on USN signs (until 4 months after the rehabilitation program) as well as an improved ability to carry out daily activities. After the

rehabilitation program, thanks to its benefits, BV took up one of her previous pastimes (woodworking) and practiced it for hours a day. This activity could potentially act to maintain benefits on USN. Our rehabilitation program may be at least partially responsible for this recovery of activity. Thus, our rehabilitation program based on music practice seemed to overcome the two major challenges of USN rehabilitation: a lack of long-term efficiency and a lack of generalization to daily life (Luauté et al., 2006). The difficulties—still reported at the end of this program in the CBS concerning left-side objects—could be more linked to BV's HLH than to her USN, as her gaze seemed to be correctly oriented according to both her auto-evaluation with the CBS and the scores in the line bisection test and in the Bells test.

Further studies are necessary to determine which aspect of our musical training procedure may be the most effective for USN. If pitches are not more efficient than rhythms, we can tentatively suggest that our observed benefits may arise more generally from the combination of sensory modalities and, in this case, from the use of the auditory modality, rather than from specifically pitch–space associations.

In conclusion, our study suggests that the use of music practice could be a promising rehabilitation tool for patients with USN.

Disclosure statement

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