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Review Article

Designing individualised exercises for violin learning: A case study of multisensory and somatosensory pedagogy

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Lyndall Hendrickson was a leading 20th-century Australian violinist and teacher, whose teaching methods were both innovative and successful. Knowledge she initially gained in self-recovery from polio led Hendrickson to investigate how violin techniques could be learned by enhancing sensorimotor perception. A qualitative case study with thematic analysis was used to discuss her exercises created for an individual student between the ages of five and eight, covering their elementary stages of learning the violin through to the study of the first movement of the *Violin Concerto in E minor* by Felix Mendelssohn. Hendrickson enriched her student's learning through a pedagogy that drew on theories of human performance, multisensory integration, redundancy, and the transfer of sensations. Her individualised violin exercises offer an original contribution to the didactical understanding of somatosensory knowledge and learner-centred approaches in developing violin technical skills.

Keywords: Case study; Individualised instruction; Instrumental music education; Mendelssohn Violin Concerto; Multisensory learning; Music didactics; Somatosensory learning; Violin pedagogy

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1. Introduction

Published violin instruction manuals may offer materials to guide the learning of instrumental skills. In the elementary stages of training, many of these manuals begin with repertoire and exercises for beginners in the first position (Chin, 2016). The idea of the left-hand remaining in first position for about the first year of learning has been a tradition since c.1650 (Mikajlo, 1994). In the 1960s, however, Hendrickson ignored this tradition and introduced her understanding of shifting motions for her students from their first lessons.

Many past studies for practising the violin have been re-published as new editions with editors marking their preferences of fingering on the scores. Hendrickson pointed out the fact that many editors have mainly been male, and in many cases the fingering has been accommodated to suit larger hands (Hendrickson, 1993). Left-hand fingering and right-hand bowing instructions, however, does impact the learning of somatosensory learning of patterns and gestures for making sound. The size, width and length of the hand or fingers, and fingertip spans are not the same for every individual. Every hand or arm posture, feeling or contact with the instrument, muscle or ligament stretches and contractions, and pressures from the weight of the fingers and the bow on the strings is recorded and mapped by the cortex. This association of motions through

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somatosensory learning was noted by Hendrickson through her study of the research by neuroscientist Walter Penfield (Penfield & Roberts, 1959). Fingering therefore is not just a matter of hearing where the fingertip needs to move to place correct intonation. It's also a map of somatosensory motions. In realising these connections, Hendrickson identified where patterns of notations or fingerings had identical or different elements (L. Hendrickson, personal communication, May 16, 2009).

When Hendrickson died she left several large boxes of her research to the author to document her methods. Her estate material included cassettes, individualised student exercise files, lectures, newspaper reports, and letters. The author had previously learned some background knowledge of Hendrickson's approaches when completing a thesis under her co-supervision at the Adelaide University (previously known as University of Adelaide). This project covered the influence of the scale of C on elementary manuals of violin instruction from 1650-1994 (Mikajlo, 1994). Though an awareness of Hendrickson's pedagogy was informed from this personal communication, further knowledge of her methods was gained through attendances at Australian Strings Association (AUSTA) national conferences, as well as from accepted invitations to watch the teaching of her young students.

To reduce any possible bias from past personal communications, and to comprehensively understand Hendrickson's philosophies and learning intentions, the author did not investigate the files of exercises until all the categorizing, coding and reviewing of the Estate materials were completed. As there are thirty or so files of individualised exercises with over several thousand exercises, the decision was made by the author to firstly investigate one case study of individualised exercises.

This is the first known examination and overview presentation of one of Hendrickson's individualised student's files (student X). The investigation comprises of tailored exercises for a student aged five to eight years. The case file findings illustrate experimental exercises that begin with elementary motions to the advanced studies for mastering the first movement of Mendelssohn's Violin Concerto. The exercises portray Hendrickson's technical solutions for assisting her student to form somatosensorial images of their performance skills. Along with her use of multi-sensory applications, Hendrickson attentively applied her understanding of the principles of redundancy, transfer, and the human performance theory when designing her created exercises. The results of this study suggest that the foundations of multisensory approaches, as well as the neuroscientific and educational theories that Hendrickson applied in creating these teaching exercises, equipped her young violin student with effective and time efficient strategies for developing their progress.

2. Biographical and Pedagogical Background of Lyndall Hendrickson

Lyndall Hendrickson (1917-2017) (see Figure 1) was a violin prodigy by the age of ten. During World War II, she was well-known as a concert violinist who performed for the Australian Broadcasting Commission, and for charity performances that raised funds for the Red Cross.

Figure 1
Lyndall Hendrickson with Sir Thomas Beecham in 1940 (Hendrickson Estate)



Shortly after the end of the war, Hendrickson contracted the bulbar form of poliomyelitis from one of her husband's patients, leaving her entirely paralyzed on the left side of her body. Her eventual recovery took over eight years in the 1950s, using a self-guided therapeutic regime that was informed by her doctor husband. Her violin technique then greatly improved through her study of educational psychology and theories of learning. This learning contributed to her reacquisition of fine motor control and provided her with an experiential foundation to form new insights into the teaching of violin skills. From the mid-1960s she imparted excerpts of her knowledge to many of her individual pupils, tertiary students and colleagues at the Adelaide University. Outside of Australia, little is known of Hendrickson's life or contributions to teaching. She wrote thousands of exercises for her violin students, and gave many lectures on her philosophies and methods (Mikajlo, 2024).

2.1. Hendrickson's Originality in Creating Teaching Methods and Materials

Although Hendrickson's own violin teacher Ludwig Schwab had been a pupil of Otakar Ševčík, her own repertoire-specific exercises do not resemble Ševčík's published studies for learning works like the concerti of Brahms or Mendelssohn (Ševčík, 1930, 1931). Like Ševčík, she wrote exercises for her students to map the left-hand vertical and horizontal fingering motions, and to master right-hand bowing techniques. Hendrickson created a series of violin exercises that, unusually for the time, required the child beginner to use vertical shifting into other positions on the fingerboard.

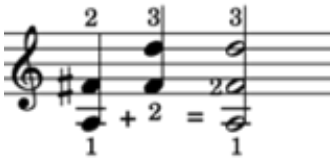
Instead of adhering to a published sequence of elementary violin exercises, such as those by Heinrich Kayser (1915), Hendrickson applied theories and her research into the then-nascent field of neuroplasticity, along with her personal experience of self-rehabilitation, by writing her own violin exercises. This included exercises for left-hand and right-hand violin skill development and identifying opportunities for somatosensory transfer. Hendrickson explained that there was so much repertoire containing every aspect of technique and that this could easily be matched to her students' individual learning needs instead of using existing studies. In violin lessons, she varied learning activities for her very young students through a mixture of stories, exercises, notations, rhythm learning, singing, and playing of pieces (L. Hendrickson, personal communication, August 20, 2009).

3. Theoretical Framework - Learning Theories That Shaped Hendrickson's Multisensory Approach to Teaching

3.1. Theory of Transfer

The theory of transfer introduced by Thorndike and Woodworth (1901) proposed that learning can occur through the transfer of identical elements between tasks and that this can improve the "training in one function on the efficiency of other functions" (p. 250). Influenced by this theory, Hendrickson stated that being able to use previous learning and transferring the skill to another situation successfully depended on the "learner being able to generalise from experience and abstract common features from similar situations" (Hendrickson, 2009). She explained that one of her young students experienced the process of transfer when they realised that sixths become a chord when another sixth is added (Figure 2).

Figure 2
"Chords" (Hendrickson, 2009)



3.2. Human Performance Theory

Hendrickson was influenced by Ronald Marteniuk's (1976) understanding of human performance theory, which explains how motor learning is achieved via perceptual, decision, and effector mechanisms. Hendrickson explained that in her students' lessons, the results of their perceptions and decisions were illustrated in how they processed tasks on the violin (L. Hendrickson, personal communication, May 16, 2009). She wrote exercises in part before, during, and after her student's lessons, analyzing repertoire for perceptual difficulties that they may encounter.

3.3. Redundancy

To simplify her students' learning, Hendrickson stated that she aligned her materials with Christopher Wickens's theory of redundancy (L. Hendrickson, personal communication, May 16, 2009). Wickens (1984) theorised that when the demands of information, such as visual clutter, create excessive cognitive loadings, it can lead to information loss. For example, the first exercises in X's file show a notable absence of clefs, keys, bar lines, and time signatures. The short exercises have hand-drawn notations enlarged with illustrations, colors to differentiate strings, and contain few instructions to avoid cognitive overload for her pupil who was then five years old.

3.4. Multisensory learning

Multisensory learning is the engagement of many forms of sensory pathways to learn skills. Occupational therapist Dr. A. Jean Ayres researched how the brain integrates information from sensory receptors to the processing of information from the body and environment that include touch, movement, and body position (Lane et al., 2019). Hendrickson used multi-sensory approaches from her use of colours, pictures, songs, vocalizations, memory cards, stories, games and motions from her training in Dalcroze Eurhythmics to engage her students learning attentions (Mikajlo, 2024).

3.5. Somatosensory learning and Mapping

The somatosensory system is defined as "the parts of the nervous system that serve perception of touch, vibration, pain, temperature, and position" (American Psychological Association, 2018). How motor learning changes the somatosensory system has been explained in later neuroscience research (Ostry et al., 2010). As a consequence of her rehabilitation process, Hendrickson (1986a) studied research on somatosensory learning, as well as theories on multisensory learning, the processing of kinesthetic information, and brain mapping. She referred to Wilder Penfield's ground-breaking research on mapping cortical function that revealed separate motor sensory and speech functions (Penfield & Roberts, 1959), observing that "since the thumb and index finger often touch at almost the same time sending their signals to the brain virtually simultaneously, the thumb map and index finger map tend to form close together in the brain" (L. Hendrickson, personal communication, May 16, 2009). She believed that the processing of brain signals involved in left-hand finger extensions, expansions, or position work on or over the strings, and that patterns of right-hand bowing motions, could be similarly mapped. The motor tasks for a violinist's right and left hands are asymmetrical and different and, in many cases, their perceptual representation in Hendrickson's learning materials are segregated before combining them together in consolidated motions to assist the learner.

3.6. Embodied Motor learning and the Impact of Polio and Hendrickson's Exploration of Neuroplasticity

Hendrickson's experience of recovering from polio and paralysis had a profound effect on her teaching. She stated that she had forced her hands to feel shapes and patterns of movements (Hendrickson, ca. 1980). It was at this stage of polio recovery that Hendrickson's surviving motor nerves were forming new connections to enable her body movements. She was at the time forming sensations of embodied motor learning. This learning is the connection and integration of motor

skills that is directly associated to psychological behavioural developments (Adolph et al., 2019). Adolph et al. stated that "Learning to move requires basic psychological functions, reflects fundamental cultural values, and facilitates learning and development across a wide range of psychological domains." (Adolph et al., 2019, p. 2). Hendrickson's additional study of educational psychology also impacted her development and creations of motor skill exercises for her students.

4. Method

4.1. Research Design

A research design of a thematic analysis was used to sort and view materials from the Hendrickson's Estate. Braun and Clarke describe thematic analysis as "a method for developing, analyzing and interpreting patterns across a qualitative dataset" through coding and theme development (Braun & Clarke, 2021, p.4). Because a great deal of the data in the Hendrickson Estate is qualitative in nature, consisting of Hendrickson's communications and reflections on her teaching materials along with the resources themselves, the author undertook a reflexive thematic analysis, using a combined deductive and inductive approach (Braun & Clarke, 2006, 2012, 2021). Hendrickson's individualised violin pedagogy is discussed through a case study approach. This provided the opportunity to focus on a bounded case: one student's sequence of individualised violin exercises from the beginning stages of learning to advanced repertoire preparation.

4.2. Research Context and Archive

The resources in the Hendrickson Estate comprise of an archival list of research materials that cover a large volume of written and multimedia sources. Included are approximately 30 individualised student teaching files, stories, handwritten exercises, workshop documents, seminars, conference presentations, lectures, published papers, as well as 3000 audio cassette recordings made between 1960–2010. The archive also includes personal communications, transcriptions of interviews with Hendrickson, and lectures she gave in The Peoples' Republic of China (Hendrickson, 1978b). Permissions to access these archival materials was given to the author by Hendrickson in 2017.

4.3. Case Selection

The pseudonym name "X" was used to report on an individualised student case study for teaching music. This complies with the University of Western Australia Ethics protocol for this research (2019/RA/4/20/5485). The study of X's file extends from May 1976 to December 1978, when they were five to eight years of age, moving from elementary lessons through to advanced exercises for the first movement of the Violin Concerto in E minor, Op. 64 by Felix Mendelssohn.

4.3.1. Why was X's file selected rather than other student files?

Henrickson wrote thousands of experimental hand-written exercises for each of her students. A comprehensive study of all these collated individualised exercises files could offer extensive knowledge on her methods and materials. The detailed analyses of all of these individual files, however, was not included, as that undertaking required a greater period of time to conduct a qualitative and comparative analysis than the scope of the current project permitted. For practical purposes this study was limited to discuss one bounded case. X's file was chosen as it enabled a qualitative study into Hendrickson's philosophies and didactical procedures for teaching one of her young violin students from the age of 5 to 8 years.

4.3.2. What are the boundaries of the case?

Whilst there has been other multi-sensory approaches as listed in a previous study (Mikajlo, 2024), a similar collection to Hendrickson's experimental exercises that reflects an individual's learning over time from the elementary stages to the study of the Mendelssohn's E minor Violin Concerto is currently unknown.

The author's previous knowledge and personal communications in working with Hendrickson has also contributed to the presentations in this study. The author's background as a violin teacher, the discussions with university supervisors as well as string pedagogy experts, may have added a bias on the discussions for this study. In reflection of this every effort has been taken by the author to investigate and report objectively on the analyses of Hendrickson's Estate materials.

4.4. Data Sources

Primary data for this study include X's file of individualised handwritten exercise sheets, handwritten excerpts of repertoire, enlarged and coloured notation, pictures and drawn imagery, stories, repertoire-specific exercises for Mendelssohn's *Violin Concerto*, memory cards and singing drills, and Hendrickson's cassette recordings of student X.

Supporting contextual data include translations of Hendrickson's Chinese lectures that were scribed for the People's Republic of China, Hendrickson's letters to Henry Roth, personal communications from Hendrickson to the author, educational psychology texts by Thorndike and Woodworth (1901), Ronald Marteniuk (1976), and Wickens (1984), Ševčík's edition of the *Mendelssohn Violin Concerto* (1931), and Yampolsky's *Principles of Violin Fingering* (1967).

4.5. Data Collection Process

The author digitised and transcribed 40 to 50-year-old cassettes from the Hendrickson Estate to sort and preserve data. This included 3000 cassette recordings teaching excerpts, rehearsals, and lectures between 1960 and 2010. Hendrickson's physical teaching documents and files that she wrote for individual students were placed in folders. Included in the collection of materials were Hendrickson's Chinese scribed lectures given in the People's Republic of China in 1978. Also examined were Australian Strings' Association [AUSTA] lectures, personal files as well her class notes presented at the Adelaide University from 1978-2010.

4.6. Data Collection Tool/s

Three audio and video cassette players were used to digitise and collect data. Physical folders and digitised files were catalogued from several boxes of unsorted materials from the Hendrickson estate. X's file was put in plastic sleeves and placed in a larger folder. The pages were numbered with a sticker on each of the protective plastic sleeves. Themes and ideas from articles written by Hendrickson, were then coded with coloured tags for potential discussions of common themes. Materials were analysed for to identify themes and patterns using a combination of deductive and inductive approaches.

4.7. Data Analysis

According to Braun and Clarke (2021), thematic analysis relies on researcher engagement with data, often guided by a research purpose or research questions, as in this research. Common themes drawn from files on Hendrickson's understanding of neuroscientific and educational psychology principles, as well as her creative teaching philosophies and materials, informed the analysis for examining X's file. These themes were also connected to the following research questions (RQs):

RQ 1) Why did Hendrickson write her own violin exercises?

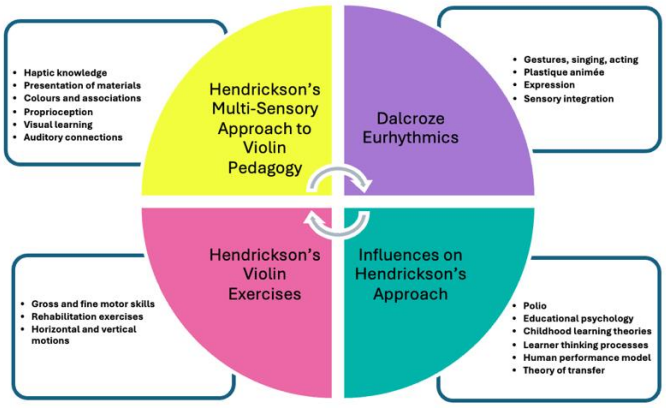
RQ 2) What methods were used to deliver their content?

RQ 3) How did X's materials and exercises for learning the violin assist their progression from elementary lessons to advanced techniques?

RQ 4) Did Hendrickson develop educational approaches that were new at the time?

The author connected previously identified Themes and sub-themes in the thematic analysis of material from the Hendrickson Estate (Mikajlo, 2024). Figure 3 illustrates these clusters of themes and subthemes the author identified through this process.

Figure 3
The inner circle represents inter-related themes from coded materials (Mikajlo, 2024)



4.8. Researcher Reflexivity and Positionality

The greater idea of Hendrickson's pedagogy was not imparted until full access was given to view the collection of materials from the Hendrickson Estate. To avoid bias as well as to explain a scientific didactical view of approaches and methods, the author chose not to conclude the report on X's case study, until Hendrickson's biographical notes, letters, lectures and philosophies were coded into subjects and organised in folders for review. Themes were then formed from the patterns of this organisation.

4.9. Trustworthiness and Methodological Rigor

Along with the advice from university supervisors in objective research methods, the examination primary and supporting contextual data was vital in expanding the author's knowledge and ability to conduct a qualitative study and well-informed view of Hendrickson's pedagogy and educational principles. The interpretation and understanding of her exercises was then analysed alongside the authors knowledge and understanding of prior communications from Hendrickson herself.

X's exercises file was chosen as the project for this study, so that Hendrickson's approaches and methods could be discussed from the themes and qualitative criteria (as in Figure 2). Hendrickson had filed X's exercises in date order, and their progression was interpreted by the skill and exercises given at a particular date. This enabled the chronological analysis of X's exercises. The file was limited from 1976 to 1978 enabling the focus on X's set tasks, from the beginner stages of their learning to the advanced techniques involved in the first movement of Mendelssohn's Violin Concerto.

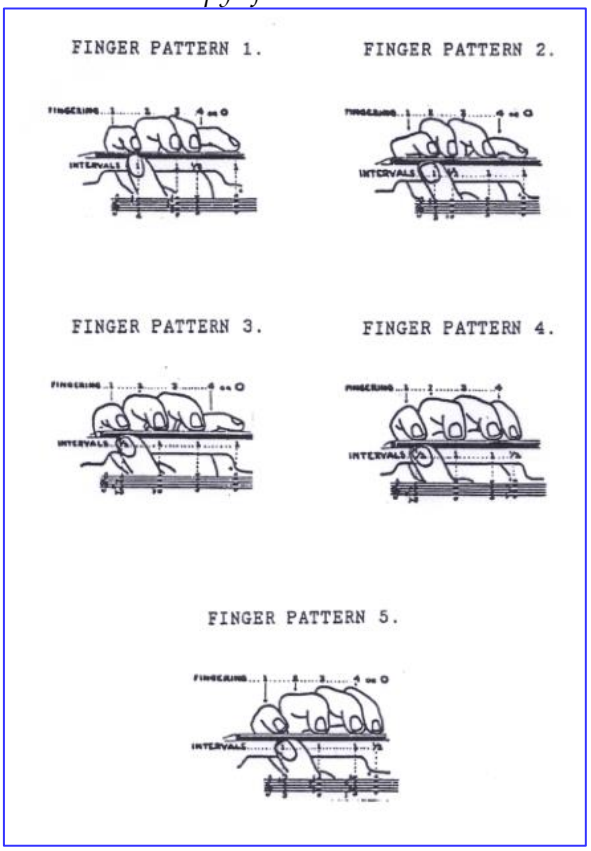
5. Findings

5.1. Introduction to X's File

The discussion of X's file is explained chronologically and includes discussions of themes, as well as the advancement of their individualised progression. Student X had a few elementary Suzuki violin lessons before attending Hendrickson's classes and evidence in their file indicates they were at the beginning stages of their violin studies. On the first lesson page, dated May 1976, X is listed as being five-and-a-half-years old. Hendrickson's exercises for X were hand-drawn and illustrated on A4 to foolscap-sized pages. She referred to these exercise sheets as weekly "drills" (L. Hendrickson, personal communication, May 16, 1992). Some of X's drills have the stamp imprint, "COPYRIGHT 1973." Hendrickson used the stamp to protect her work; however, for each lesson there was a handwritten date on each page, stating only the month and year. Alongside some elementary exercises were copies of children's tunes i.e., *Polly Put the Kettle On,* and *This Old Man,*

dated July 1976. Hendrickson stated that many of the elementary tunes she used were based on those in the *Oxford Book of Nursery Rhymes* (Buck, 1933). She based her arrangement of such repertoire in elementary lessons on finger patterns as set out by Joseph E. Skornicka and Roland L. Moehlmann (1952) in Figure 4. Hendrickson stated that with the widespread acceptance of these finger patterns "in elementary instruction by the mid-twentieth century, it was possible to offer an extended range of tunes" (Hendrickson, 2001).

Figure 4
Hendrickson's copy of Skornicka and Moehlman's finger patterns (Hendrickson, 1992-1993, p.7)



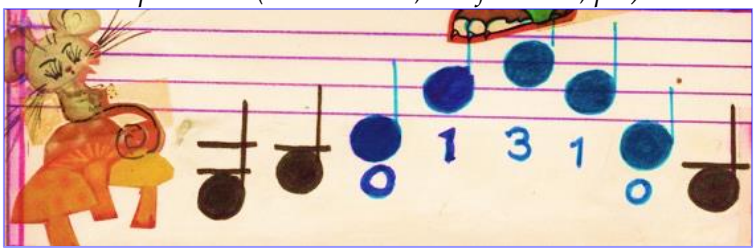
5.2. X's Early Lessons: Use of Somatosensory and Visual Stimuli

From X's first lessons Hendrickson had introduced concepts that dealt with the early preparations for performing advanced repertoire, by instructing that the left-hand and finger motions should move in an exploratory way out of the first fingerboard position. X's first violin exercise only involved a guided experience early somatosensory awareness with the left-hand second finger pressing down and releasing the G string in a sequence of movements ascending the string (X's file, 1976). For this Hendrickson illustrated only the note B on the G string, followed by the open G string note with an arrow symbol pointing upwards. This exercise had the student lift and press the second finger as if taking it for a walk or hopping up the string. There was freedom in the structure of this exercise, as it could be played by ascending the strings by shifting in half steps or by locating notes of the G diatonic scale. This preparatory exercise enabled young X to form intuitive perceptions of varied left-hand finger-pad pressures when ascending the strings. Hendrickson explained that when teaching young children, it was important to include the open string as part of their exercises to learn left-hand fingering. This helped her students' awareness of the muscles' contractions to play stopped fingering on the strings, and released left-hand tension when playing the open string (Hendrickson, c.1980).

X also learned the G major arpeggio with the D-string notes highlighted in blue notation (Figure 5). Hendrickson used this exercise to ascertain if X could perceive how to locate the higher octave

notes of G and B with their fingers in the third position, even at this early stage of learning. This contrasted with traditional 20th-century violin teaching manuals in use at the time, such as Hohmann's *Practical Violin Method* (1910), which provides elementary violin exercises only in the first position. Hendrickson was following the then-unconventional advice of the Russian violinist and teacher, Abram Ilich Yampolsky (1967), who wrote that it was necessary in early violin teaching practices to introduce movements that included all the different positions along the fingerboard.

Figure 5
"Into third position" (Hendrickson, X's file 1976, p.3)



5.3. Reducing Cognitive Load through Visual and Multisensory Scaffolding

To enhance X's early learning of musical notation, Hendrickson enlarged the exercise notation with notes on each string differentiated by color (Figure 5). In 1980, Hungarian brothers Géza and Csaba Szilvay published their *Colourstrings* method for the violin and cello, also using different string colors (Szilvay, 1980). There is no evidence that Hendrickson or the Szilvay brothers were aware of this similarity in integrating multisensory learning into their respective approaches to string teaching at the time. Hendrickson was influenced by Ralph William Pickford's study on children's color stimuli (Pickford, 1972), and was already using color in her teaching in the 1970s. This extended beyond string identification: she noted that using yellow as a background colour competed for less attention by a child when placed alongside other colours, such as blue and red. The colours Hendrickson used in X's file were not merely to draw the student's attention to notes on different strings but to attract their attention to similarities and differences in patterns and their transfer in different tasks on the violin.

Hendrickson's use of such visual stimuli as means of promoting notational literacy in her students is also indicated in a lecture she gave during her first visit to the People's Republic of China in 1977. There, she showed a picture of "Mister G" (Figure 6), stating that X placed this image on a mirror or door at home to associate Mr. G's visual notation with him sitting under two lines, as well as to help remember his sound (Hendrickson, 1978c).

Figure 6
"Mr. G Card" (Hendrickson, X's file 1976, p.2)



5.4. Imagery as Learning Motivation

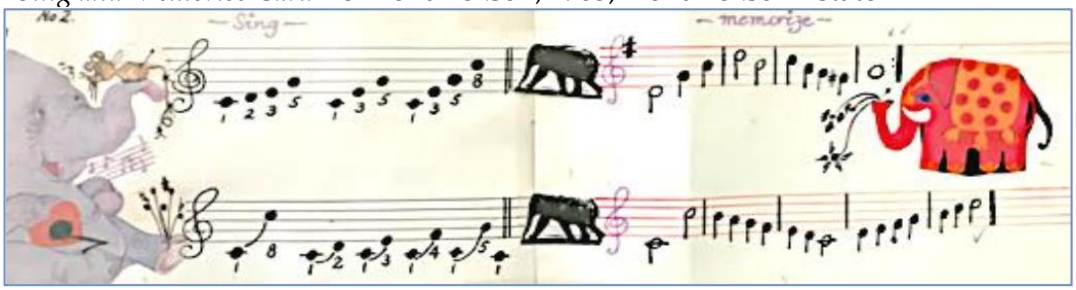
In addition to Hendrickson's use of colours, she created many pictures and stories for her drills and pieces she taught her students. Use of imagery was something that she had learned from her study of Dalcroze Eurhythmics as a child. As the founder of Eurhythmics, Émile Henri Jaques-Dalcroze explained, there need to be connections from the mental image of a motion to the

performance of it by the body (Jaques-Dalcroze, 1920). Hendrickson often encouraged students to find several ways to vocalise or express a simple passage to enhance her students' sensorimotor learning and encourage movements needed on the instrument. X's file accordingly features pictures of animals to help X connect with emotions and expressive gestures in the music, such as Crescendo the lion, who roared to make his voice louder, and Knotty Squeaker the mouse, who had knots in his tail when he needed to remember something (Hendrickson, 1978a).

5.5. The Use of Memory Cards

Hendrickson provided singing cards for students to promote their auditory memory skills, the reading of notations, and forming an understanding of intervals. The notated bars had to be sung at home without the instrument and only later were played from memory at the student's next lesson. X's original memory cards were not located in the archives of the Hendrickson Estate. However, Figure 7 provides an example of one of Hendrickson's memory cards for another student. This exercise shows how Hendrickson visually simplified the elementary level-notation by writing note stems in one direction (at the request of one of her young students), while at the same time using engaging pictures and drawings of animals, as well as red-coloured stave lines for the bars indicated to be memorised.

Figure 7
"Sing and Memorise Card" © Hendrickson, 1983, Hendrickson Estate

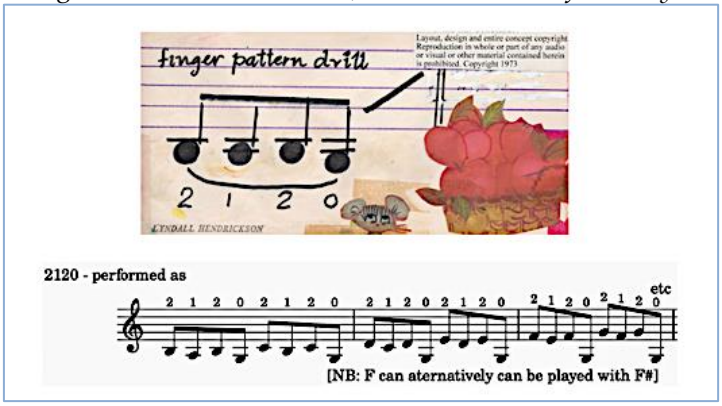


5.6. Transfer of Finger Patterns

In traditional violin methods, finger pattern studies have often been given to students to strengthen the independence of left-hand fingers. Many forms of such exercises have been published over time, such as those by Ševčík (1881). The hand and fingers have a complex network of tendons, muscles, and ligaments that operate the physical motions of playing the violin, but the actions of fingers are not always naturally independent. Kinesiologists Zatsiorsky et al. (2000) reported that multiple fingers produce a certain force even when the motion of a single finger is intended. They termed "enslaving" as "the involuntary force production by non-intended fingers" (Zatsiorsky et al., p.187). The successful performance of left-hand violin fingering techniques, however, does require that individual fingers be trained to move with some independence.

Neurophysiology researchers Hirano et al. (2018) explained that "skilled sequential finger movements are acquired differently through implicit and explicit sequence learning" (p. 573). They describe that implicit learning involves processes where the student is naive in what they are studying. In contrast, in explicit learning the student "consciously learns the order of elements of a sequence" (Hirano et al., 2018, p. 573). Hendrickson had been forced to reorganise the learning of patterns and fingering coordination after her long-term experience of paralysis from polio. In X's file, she used some implicit ways of introducing fingering patterns, such as a sung short phrase, "I can see you", or a small sequence of patterns, as in "Exercise 2120" (Figure 8). The student had the task of singing and relying on their auditory or kinesthetic senses to locate the finger placements. Such shorthand-like exercises were sometimes performed in lessons with Hendrickson harmonizing on a small handheld organ.

Figure 8
"Finger Pattern Drill 2120" (Hendrickson, X's file, May 1976, p 3.)



These examples of individualised exercises illustrate how Hendrickson taught the transfer of vertical movement sequences along the fingerboard. Hendrickson gave minimal information to the student, eliminating that which was redundant, with only an arrow indicating that the pattern should be transferred through all the positions on the G string. String tensions differ for each note on the violin as the strings are at different incremental heights across, and up and down the fingerboard. Hendrickson exposed X to the entire length of the fingerboard in early exercises, helping them adapt to the feel of changing string tensions for the left hand and bow, and enhancing their somatosensory inputs in the very first lessons.

5.7. Economizing in the Learning of Patterns

Somatosensory motions for performing pitches may differ on each of the violin strings. Hendrickson stated that when learning to perform motions through her simple finger patterns on the G string, it enabled her students to replicate their learning of intervals in parallel motions when played on other strings (L. Hendrickson, personal communication, May 16, 2009). Unlike Ševčík's elementary studies (1903), where each exercise was written out on every string, Hendrickson wrote out many elementary finger exercises only as a few short bars to indicate a sequence of ascending motions on the G string. These exercises were not performed descending on the G string nor repeated on neighboring strings. This reflects Hendrickson's conscious decision to economise her student's time, their cognitive and physical load. She specifically chose the G string for these types of exercises, to establish at the early stages of learning, the left-hand and arm position for playing across all four strings (L. Hendrickson, personal communication, May 16, 2009).

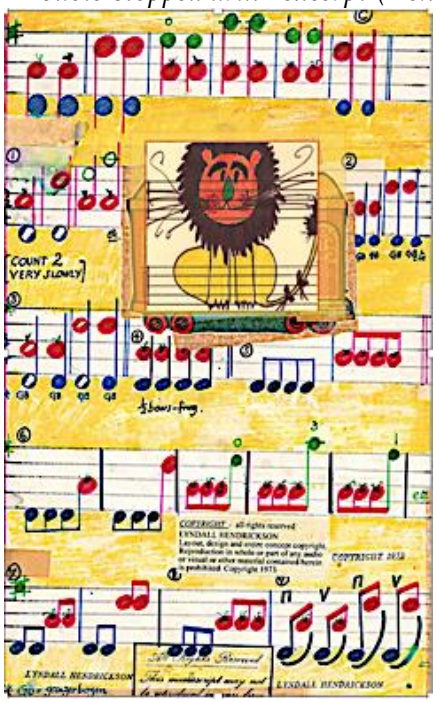
5.8. Reducing the Cognitive load via Exercises for the Right Hand and Coordination with the Left Hand

Hendrickson explained that she often gave exercises such as "stuck in the mud," where the student was allowed to make sounds that mimicked the weight of different animals flying down to the strings with the bow; for example, a heavy scratchy sound of an elephant or the smooth, light sound motions of a butterfly (L. Hendrickson, personal communication, May 16, 2009). In the exercise in Figure 8, Hendrickson indicates that left-hand finger patterns should be played with separate bows or slurred in four notes. This was to encourage the student to perceive the correct right-hand and arm weight for bowing as well as the speed and amount of bow needed for each note. These early slurred patterns also allowed the student to measure out the bow only on one string, without having to make additional right-arm adjustments for string crossings on multiple strings.

Similar to Ševčík's approach in his *School of Violin Technique*, Op. 1 (1881), Hendrickson used many different techniques to consolidate fingering techniques such as targeting notes, isolating difficulties, doubling speeds, and introducing bowing variations. For example, in Exercise No. 3 in the *School of Bowing Technique* (1901a), Ševčík wrote 57 bowing variations to consolidate bow

divisions using varied rhythms for the same finger patterns played on the G, D, A, and E strings. Hendrickson adopted Ševčík's practice of composing bowing variations for a single melodic excerpt. However, in contrast to Ševčík's "saturation of solutions" (O'Brien, 2018, p.94), she drew on her knowledge on the theory of redundancy to reduce the number of exercises and include only what she felt was necessary. In June 1976, Hendrickson introduced X to a double-stopped drill including intervals of fifths, sixths, and octaves (Figure 9). She wrote bowing variations for the melody to familiarise the student with playing on two strings, using varied bow lengths and string crossings. This allowed X to learn the sensation of weight transfer in bow strokes and the changes of bow direction using varying bow speeds. This example again shows Hendrickson's use of a yellow background to visually highlight the musical notation appearing on different staves.

Figure 9
"Double-stopped drill" excerpt (Hendrickson, X's file, June 1976, p.9)



5.9. "Hidden" Learning and Encouraging Self-discovery

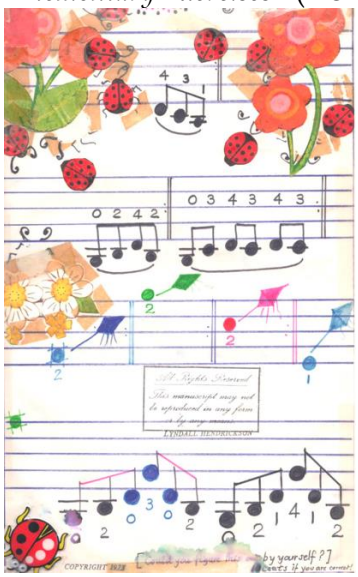
Hendrickson's early introduction of advanced principles of shifting and finger-pattern work, and exercises to move the left hand out of the first position, encouraged students to experience fingering and sounds on different areas of the fingerboard. From X's first lessons, Hendrickson's use of "hidden" learning is evident in the embedding of advanced movements and concepts in elementary exercises. For example, in Finger Pattern Drill – 2120 (Figure 8), the interval spacings for both major and minor seconds are introduced and then transferred as the fingers ascend through the position changes on the G string. This exercise introduced X to the interval of the minor second when the left hand moves into second position. In July 1976, two months after X began lessons, Hendrickson wrote out notations for Polly Put the Kettle On, which included the minor second interval when playing the C natural on the A string. Prior learning of the finger formation for the interval of the minor second in drill 2120 meant that X had already developed the sensorimotor awareness needed to play this interval when encountering it later in more advanced repertoire.

X was only five years old and still a beginner when Hendrickson wrote the elementary exercise illustrated in Figure 10. The ascending finger motions on the G string encouraged X to find the locations of major and minor thirds between the second and fourth fingers (Bar 2), as well as between the first and third fingers (Bar 1). Hendrickson also gave X exercises for other fingered

interval distances, between the first and fourth fingers (Bar 1) and the third and fourth fingers (Bar 3).

Such actions, where fingers measure and associate the physical space of an interval or from one movement to another kinesthetically, are part of the somatosensory learning process. Hirano et al. (2025) conducted experiments to measure the representations of sensorimotor processing in pianists and non-musicians. They concluded that "pianists have enhanced inhibitory function (conscious control of body response) in the somatosensory system, which isolates the processing of somatosensory afferent (receptors) inputs from each finger" (Hirano et al., 2025, p. 45). We can speculate that in giving X such exercises, Hendrickson was assisting her student to discover and attend to the somatosensory afferent (neural receptor) inputs from left-hand fingering actions over the strings when calculating the distance of intervals, as well as encouraging them to apply appropriate finger pressure on the strings to produce a good sound.

Figure 10
"*Elementary Exercises*" (Hendrickson, X's file, 1976 p.12)



The last line in Figure 10 illustrates a G major arpeggio played on the G (black) and D (blue) strings. In the repeated notes of the arpeggio, Hendrickson invited X to figure out how to play it, writing under this exercise: "[Could you figure this out by yourself] 10 cents if you are correct" (X's file, 1976 p.12). This exemplifies an early discovery task Hendrickson set for X to enable the transfer of previously learned auditory and kinesthetic knowledge to other areas of the fingerboard.

5.10. Finger Slides

The third line of X's drill sheet in Figure 10 includes short exercises comprising sliding motions, named "Kites or Glide Ohs," to help X explore the sensation of finger pads sliding up the strings as far as possible, as if flying off into the sky. Hendrickson encouraged her five-year-old student to have the freedom to glide over the entire length of the string as a fun activity in elementary learning. Awareness of the muscular effort needed to press the strings down can differ between each student. Hendrickson stated that she helped some students feel the experience of fingers sliding by actually putting some "grease" (a mixture of lanolin and bees wax) on her pupils' fingerboards. She also used analogies, such as unlocking a "seized engine," to promote associating fingertips with sliding and oscillating movements on the strings (L. Hendrickson, personal communication, May 16, 2009). By acquiring such sliding ability early in their learning, students learned that unstopped fingers shared elements involved in microtonal movements, glissando, vibrato, finger shifts, chromatic shifts, and double-stopping.

In this regard, Hendrickson was again influenced by Yampolsky (1967), who noted that there were degrees of sounds that are joined through fingertip motions from one note to another that may not be noticed in an actual violin performance. He stated that "the way in which the performer moves from sound to sound [the time and calculated weight of finger motions in shifts between notes] is one of the most important factors in artistic performance" (Yampolsky, p. 119). Hendrickson's early emphasis in X's first lessons on adjusting the weight of fingertips to play glissando along the strings appears to adopt Yampolsky's advice that such slides are an important technical element in early violin learning.

5.11. Early Introduction of the Half Position

When reflecting on Ševčík's pedagogical work through his "Semitone System" (1901b) and *School of Bowing Technique, Op. 2* (1901a), Hendrickson wrote that it represented an "exhaustive and detailed exposition of every technical task, which the two hands are ever likely to encounter" and that "every possible solution is presented" (Hendrickson, 1992–1993, p. 30). Although she admired Ševčík's legacy, she was critical of his instruction to extend the first finger back from the first position rather than moving the hand back to reach half position. By omitting this in the first volume of his beginner books, Hendrickson (1992–1993) thought that Ševčík had "failed to provide for its study … where it should have found a place" (Hendrickson, p. 30). She further pointed out that this decision was surprising as Ševčík "covers every possible contingency likely to arise from lowering the first finger a semitone from the first position" (Hendrickson, p. 30). Yampolsky (1967) said it was "essential to introduce systematically into early learning teaching practice new kinds of movements and positions of the fingers on the fingerboard" (Yampolsky, p. 118), which included the enharmonic changes of intervals and the half position. In the early 1970s, Hendrickson adopted Yampolsky's advice, introducing changes of positions and using the half position in her elementary violin exercises. This is evident in X's file (1976) where she introduced the half position by having the first finger trilling on a G sharp on the G string, making a buzzing noise, which she illustrated with a picture of a bee.

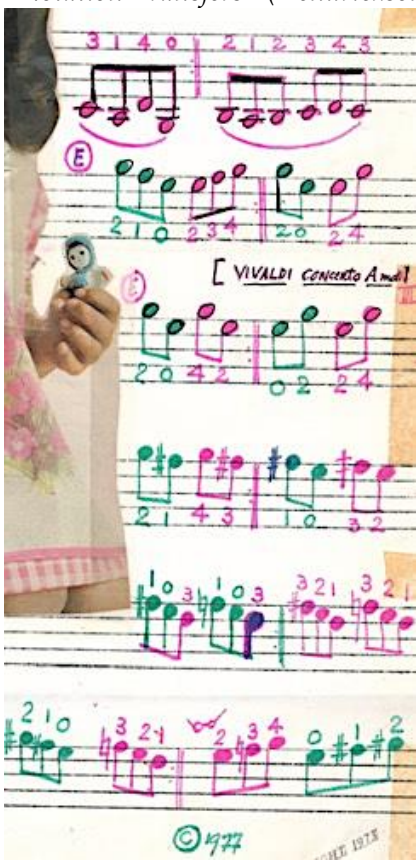
5.12. Preparations for advanced repertoire - Learning of Three-octave Scales

In a lecture Hendrickson gave in Shanghai on March 20, 1978 (Hendrickson, 1978c), she stated that learning to play three-octave scales in Australia or America could take a violinist many years. She referred to X's learning progress, telling her audience of Chinese teachers that some of her students were preparing to perform three-octave scales at the age of 5 years. In 1978 during another lecture in Beijing, Hendrickson (1978c) indicated that she prepared her pupils by first introducing varied finger-shifting exercises and glissando movements related to scales to develop early independent finger motions. As early as June and July 1976, when X was still 5 years old, Hendrickson introduced a one-octave G major scale, played with only the first and second fingers ascending the G string. She repeated this type of exercise in X's drills from July to October, 1976, along with other fingering exercises, to introduce X to components of three-octave scales and arpeggios. By that November, when X was 6 years old, Hendrickson assigned the three-octave G major scale and arpeggio.

5.13. Transfer Exercises from X's File

In May 1977, Hendrickson again used color to assist X's connections between auditory perception and fingerboard location transfers in repertoire. For example, excerpts of exercises in Figure 11, line 2, illustrate a sequence of notes on the E string (in green) that X was then required to transfer to the A string (in pink). Hendrickson marked this "E" as an experimental exercise that was related to X learning shifts required in the *Violin Concerto in A minor* by Antonio Vivaldi.

Figure 11
"Notation Transfers" (Hendrickson, X's file, 1977, p.43)



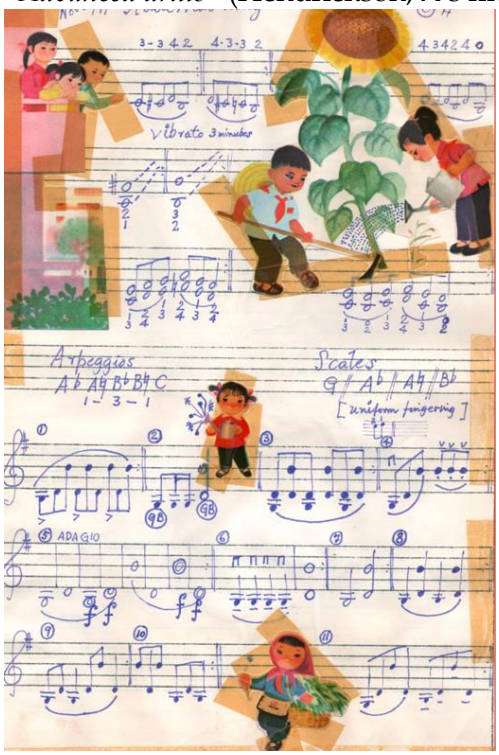
The early experience of these types of exercises assisted X in learning the transfer of notations and finger motions when performing pitches while ascending the violin strings and playing in higher registers as well as locating micro-adjustments of smaller interval distances.

5.14. Advanced Drills

By November 1977, when X was 7 years old, Hendrickson decorated one drill page with children's pictures she had received as a gift while lecturing in the People's Republic of China that year. The drill page in Figure 12 shows X's progression in the tasks Hendrickson had set: finger patterns ascending the G string, double stops, arpeggios, and scales. The three-octave scales and arpeggios required the same sets of fingering patterns. The sets of major scales that begin with the first finger on the G string, all use the same fingering and interval sequences (Figure 12).

In the second line of Figure 12, the first bar introduces major sixths, where the first finger is placed on A (on the G string) and the second finger on F sharp (on the D string). In 1994, at a lecture at the Adelaide University, Hendrickson explained that these sixths could be played while ascending or sliding up the strings in semitone motions (L. Hendrickson, personal communication, May 1994). The last three lines illustrate bowing variation exercises, where right-hand tasks include sustained, accented bow strokes, slurred détaché, up-bow staccato, and slurred string crossings. The demands of these drills show that by this time, X was already learning more complex and advanced bowing motions. They exemplify Hendrickson's practice in exercises of isolating patterns of left- and right-hand techniques before asking the student to combine them in their playing.

Figure 12
"*Advanced drills*" (Hendrickson, X's file, November 1977, p.51)



5.15. Specific Exercises for the First Movement of the Mendelssohn Violin Concerto

The techniques discussed above in X's file indicate that, at the elementary learning level, X had already been given many exercises to master the motions of left-hand fingering, position changes, sliding techniques, double-stopping, and bowing. After the first three years, when X's reading of notations had become more advanced, Hendrickson began to illustrate exercises using less color, although it was still used to highlight elements in pattern-work passages and focus X's attention on pattern changes.

By December 1978, when X was eight years old, Hendrickson wrote preparatory exercises for study of the first movement of the *Violin Concerto in E minor*, Op. 64 by Felix Mendelssohn. Like Ševčík, Hendrickson composed repertoire-specific drills for Mendelssohn's *Concerto* (1978a). However, a comparison of Hendrickson's exercises with those in Ševčík's *Elaborate Studies and Analysis Bar by Bar of F. Mendelssohn-Bartholdy: Konzert in E-Moll* (1931) shows that they were distinctly different. While Ševčík published 29 pages containing multiple sets of exercises just for the first movement of the *Concerto*, Hendrickson only produced 13.5 handwritten pages of exercises, individualised to match X's skill level and learning capacity, and focusing on the skills that X needed to further develop. Hendrickson's originality is evident in the way she set these exercises within a story about "Crescendo" the lion, whose ambition was to perform Mendelssohn's *Violin Concerto*. As Crescendo is challenged to learn some of the notated leaps, he is assisted by many animals familiar to X at the Adelaide Zoo, each of them had a role to play in the work. This includes "Forte" the frog, "Stavo" the zebra, "Tranquillo" the koala, "Lofty" the giraffe, and "Knotty Squeaker" the mouse. A small quote from the story below illustrates Hendrickson's humor and pedagogical creativity:

> Crescendo decided to take lessons from Professor Katto. "I'd like to play the Mendelssohn Concerto, Professor," he said. "I appear in it 60 times ... although my name has been shortened to 'cresc.' But ... of course it won't affect my ability to roar in those passages where my name is written, those bars belong to me." (Hendrickson, 1978a, p.3)

5.16. Hidden Somatosensory Learning in Exercises for the Mendelssohn Concerto

The way Hendrickson wrote these exercises for the first movement of the Mendelssohn *Concerto* suggests that they were intended to promote X's perceptions and associations in somatosensory learning. For example, in Figure 13, Hendrickson wrote the fingerings to draw X's attention to the similarities and differences when transferring finger placement sensations. The first and second bars use identical fingerings for execution of whole and half steps (Figure 13). In the first bar, Hendrickson encouraged X to sense and locate D sharp when the left hand was anchored in the third position, before locating the same note starting from the first position in the following bar.

Figure 13
"Crescendo" and Drills for Mendelssohn's Violin Concerto, Op. 64 (Hendrickson, 1978a, p.5)



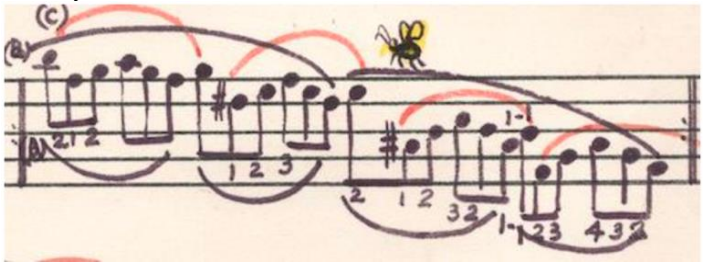
When performing in the third position, kinesthetic memory of the hand location on the fingerboard can be associated with the fingers, wrist or parts of the palm. The palm or wrist of the left hand may be anchored closer to the upper bout of the violin and can form a sensory memory of where it touches the violin when the fingers are in the third position (Figure 14).

Figure 14
Left Hand in First and Third Positions (Photo by Author)



In Figure 15, Hendrickson introduced different bowing variations (a, b, and c) to consolidate the timing of the left-hand triplet patterns in Bars 25-27 of Movement I in the *Concerto*. Hendrickson's minimal use of color here makes the "bee symbol" stand out as a sign for her young student to shift rapidly to the A sharp and half position. Bowing variation (c) in red indicates the original printed articulations for this passage.

Figure 15
Drills for Mendelssohn's Violin Concerto, Mvt. 1, Bars 25-27. (Hendrickson, 1978a, p.5)

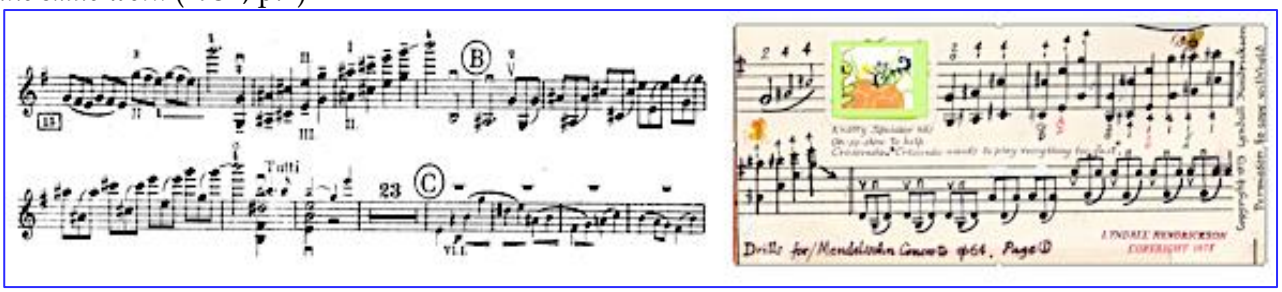


To learn the octave passage in Bars 40-47 before rehearsal marked "B", Hendrickson gave X individualised preparatory exercises to practice intervals and finger motions (Figure 16). To cater for X's eight-year-old hand size and anthropometry, and to stabilise the feel of the fourth finger

reaching A# on the D string, like Ševčík, Hendrickson fingered the first G octave with the second finger on the D string. Hendrickson also isolated elements, such as sections of the octaves for practice. On the last line, she isolated the open string bowing patterns so X could learn the coordination of right-hand motions for the triplet octaves.

Figure 16

Hendrickson's Drills for the Mendelssohn Violin Concerto, Mvt. I, Bars 40-47, Alongside Ševčík's score of the same work (1931, p.1)



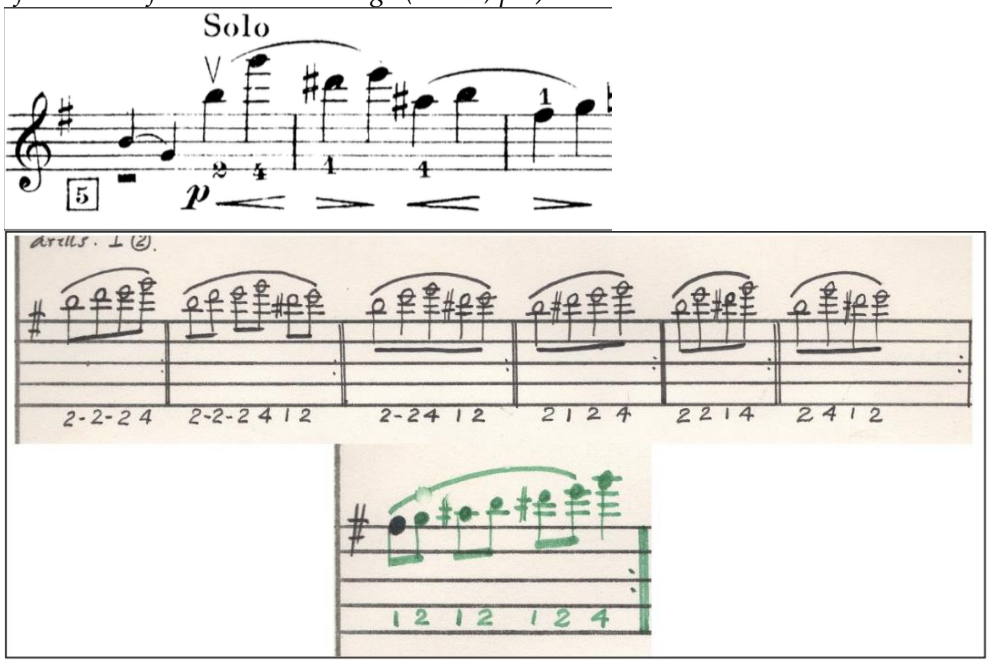
Note. Hendrickson's last bar on the top line is missing the A# and C# octaves where she accidentally wrote them together as a tenth interval (1978a, p.5).

5.17. Inversions of Notations to Learn Left-hand Placements

In Figure 17, Bars 76-78 begin on the E string with the interval ascending B to G using the second and fourth fingers. Hendrickson's solution when teaching these motions to X was to create several short bars of exercises, where the fingering indicates shifts for the left hand between the third, fifth, and sixth positions. She thought that children could understand shifting patterns and hand positions by first learning ascending motions for intervals and fingerings on the fingerboard, before learning descending motions (L. Hendrickson, personal communication, May 6, 1992). The last bar in the exercise illustrated in green notation, clearly shows her inversion of such finger motions when ascending the E string.

Figure 17

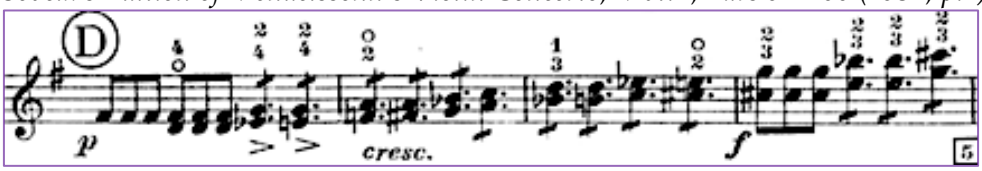
Ševčík's edition of Mendelssohn's Violin Concerto, Mvt. I, Bars 76-78, Followed by Hendrickson's Solution of Exercises for the Same Passage (1978a, p.7)



5.18. Dealing with Double-stopped Fingering in the Mendelssohn Concerto

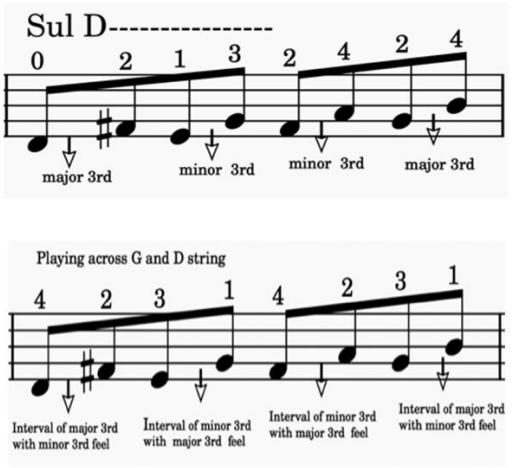
When performing double-stopped movements on the violin, the sensory processing of muscle contractions or expansions can vary widely between individuals. Unique physical characteristics i.e., finger lengths, shapes, width, levels of flexibility and/or joint hypermobility (Yildiz et al., 2024) contribute feedback to the performer. Hendrickson studied Ottó Szende and Mihaly Nemessuri's text on the *Physiology of Violin Playing* (1971) focusing on research about the functions of spindles (L. Hendrickson, personal communication, May 16, 2009). Spindles are receptors that measure muscle expansions, contractions, levels of weight, force, and the speed of motions (Kröger & Watkins, 2021). Hendrickson was aware that holding finger placements while performing double-stopping in thirds on individual or adjacent strings can provide additional proprioceptive information, e.g., the degree of involved finger depressions or stretches and contractions needed to perform certain intervals. Holding down fingers in this manner can be physically strenuous for those who possess a short fourth finger or have extremely low muscle tone or flexibility. In some cases, the holding down of the fingers could "impede the elastic joint motion of the fingers" (Szende & Nemessuri, 1971, p. 62). Leaving fingers down on the strings may be suitable when it assists in executing tasks and is needed for "succeeding fingers intonating or motor orientation" (Szende & Nemessuri, p. 62). Beginning in Bar 97 (Figure 18), there are double-stopped thirds where the fingers are held down over repeated triplet rhythms. The fingers adjust kinesthetically with half-step motions to perform the progression of thirds as shown in the following excerpt.

Figure 18
Ševčík's Edition of Mendelssohn's Violin Concerto, Mvt. I, Bars 97-100 (1931, p.2)



When performing thirds on the violin, there are complications in processing fingering distances that occur when reading the patterns of major and minor intervals. Kinesthetic associations for measured finger spacings in intervals of the major and minor thirds correspond when played only on one string, but the same measurements do not apply when these intervals are played across two strings, as seen in Figure 19.

Figure 19
Thirds on D String, Followed by Thirds Over Two Strings (Diagram by Author)



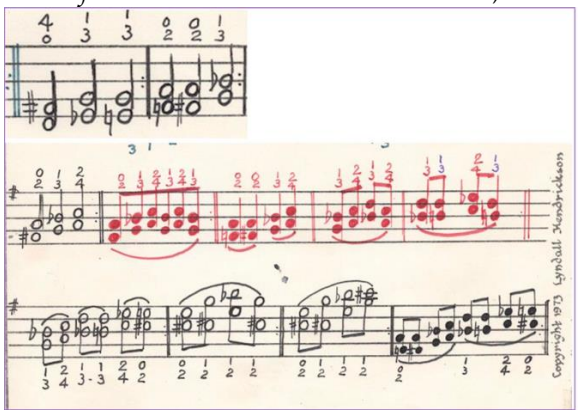
Yampolsky (1967) noted that there are hidden degrees of sounds that occur when the fingertips glides on the strings from one note to another. Such motions are involved in the refined auditory processing, proprioceptive awareness, and the subtle adjustments of finger actions to correct

intonation when performing double stops on the violin. These motions can involve a "minute squeeze of one or the other fingertips in relation to each other, in order to correct barely discernible false intonation" (L. Hendrickson, personal communication, May 6, 1992).

Hendrickson individualised the fingerings written in Figure 20 to suit X's left-hand physical abilities, and to assist them in recognizing the patterns of motions intertwined with different muscle contractions and extensions. Hendrickson omitted the triplet rhythm, breaking down the transitions of left-hand fingering into small, repeated patterns. She also introduced a change of focus in bowings and rhythms, so the student could learn to synchronise them with their left-hand pattern work. Her addition of practice slurs also assisted X in right-hand production of a sustained tone with the bow. This enabled X to concentrate on intonation accuracy in fingering, and the refinement of their fingertip glide motions between notated double stops.

Figure 20

Drills for Mendelssohn's Violin Concerto, Mvt. I, Bars 97-100 (Hendrickson, 1978a, p.7)

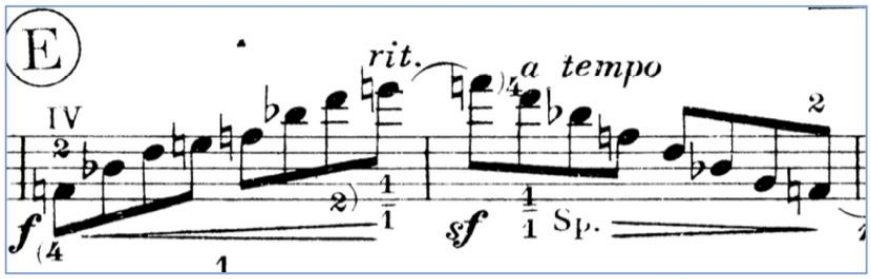


5. 19. Coordinating Left- and Right-hand Skills in the Mendelssohn Concerto

The following example from the *Concerto* in Figure 21 illustrates an arpeggiated passage that involves both, string-crossing and left-hand fingering shifts.

Figure 21

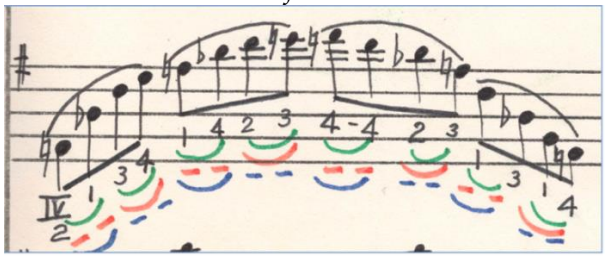
Mendelssohn's Violin Concerto, Mvt. I, Bars 113-114, (Ševčík edition, 1931, p.2)



To coordinate the timing of both, bowed string crossings and the different forms of shifting, Hendrickson gave X bowing variations, such as four notes to a bow or two notes to a bow as well as slurred and détaché combinations of bow strokes, as illustrated in Figure 22.

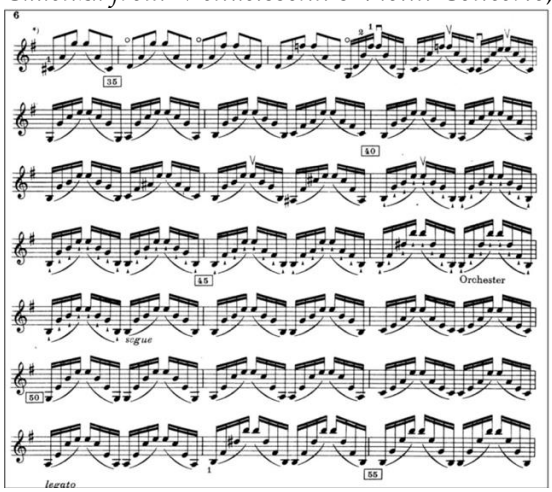
Figure 22

Hendrickson's Exercise for Mendelssohn's Violin Concerto, Mvt. I, Bars 113-114 (1978a, p.9)



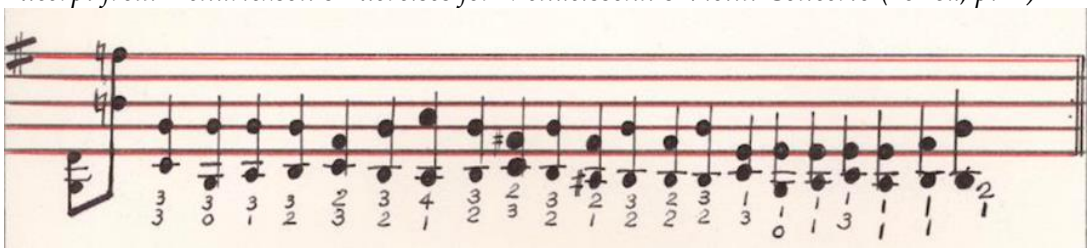
At the end of the cadenza section of the first movement, left-hand intervals need to be coordinated with right-hand arpeggiated ricochet (saltando) bowing over all four strings as shown in Figure 23.

Figure 23
Cadenza from Mendelssohn's Violin Concerto, Mvt. I, Bars 322-338 (Ševčík edition, 1931, p.6)



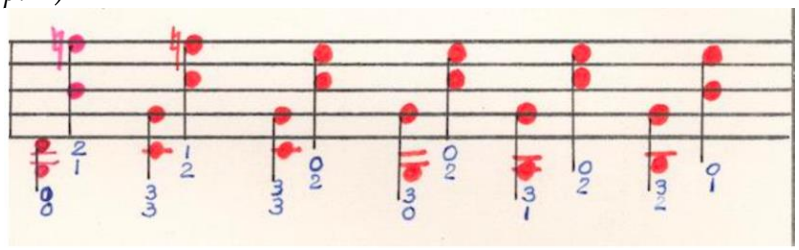
Hendrickson's solution is to split the left-hand fingering pattern work by writing out only the first two notes of each bowed sixteenth-note pattern as double stops (Figure 24). This exercise helped X focus on harmonic changes and develop kinesthetic patterns in left-hand motions.

Figure 24
Excerpt from Hendrickson's Exercises for Mendelssohn's Violin Concerto (1978a, p.11)



Hendrickson then introduced the upper notes in-between these double stops as shown in Figure 25. To simplify X's visual perception in some exercises, Hendrickson again ignored notational conventions and deliberately wrote stems only in one direction.

Figure 25
Lower and Upper Double Stops from Hendrickson's Exercises for Mendelssohn's Violin Concerto (1978a, p.11)



5.20. Exercises for Transition from Legato to Ricochet Bowing in the Cadenza

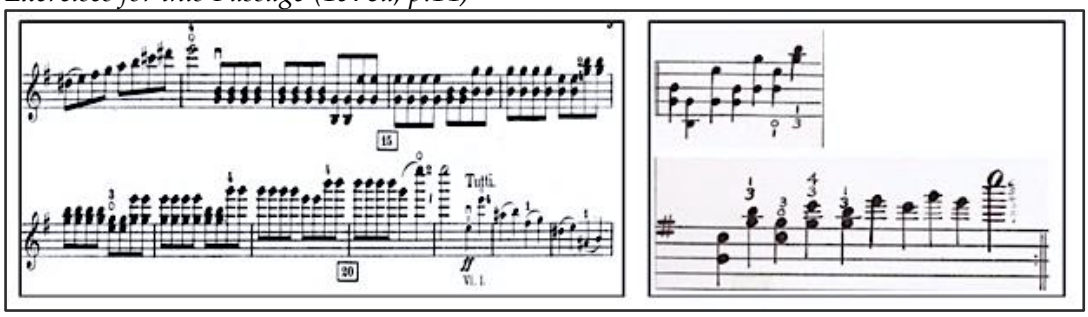
Hendrickson's solutions for the cadenza's left-hand tasks may have allowed additional time for X to learn the right-hand techniques. Just how Hendrickson taught X to make the transition of right-hand legato bow strokes to arpeggiated ricochet bowing in the cadenza (Figure 22) is not shown in X's file. However, this may be deduced from a reflection on arpeggiated ricochet bowing by Hendrickson's other student named "Y" who wrote:

> A four-string exercise was given, and the drill consisted of combining the ricochet stroke in conjunction with the détaché stroke. Beginning in the middle of the bow, a slight kick was given by the wrist with the object of making the bow unstable in the first two strokes ... thus establishing the actual ricochet or bouncing off ... by combining the strokes, it was possible to observe the differences in arm weight, wrist motion and other factors involving the bouncing motion ...
> ("*Discovery learning on the arpeggiated ricochet*" June 3, 1976. Permission from the Hendrickson Estate)

This student's ability to recognise the bow strokes, larger arm spans, and the subtleties of wrist and finger motions when mastering the arpeggiated ricochet demonstrates their ability to transfer previous learning when gaining the skill needed for this new, complex task. Hendrickson's application of Marteniuk's human performance theory in her teaching may also be evident in this student's report, as it shows their perception of the task, decision of how to practice it, and evaluation of the outcomes (Marteniuk, 1976).

For Bars 503-512 (Figure 26), Hendrickson individualised X's fingering and reduced the rhythms of the chord changes from eighth notes to quarter notes. This encouraged X's awareness of interval patterns, as well as somatosensory learning through memorizing left-hand shapes, the sensation of muscular contractions and extensions, and position shifts. It also allowed X to attend to the angles of right-arm string crossings and to calculate the necessary weight, bow hair and string tensions when performing each of the double stops while ascending the strings.

Figure 26
Mendelssohn's Violin Concerto, Mvt. I, Bars 503-512 on the Left (Ševčík edition, 1931), and Hendrickson's Exercises for this Passage (1978a, p.14)



6. Discussion, Limitations and Future Research

Hendrickson's approach contributes to instrumental music didactics by her encompassing so many educational neuroscientific and psychological principles, as well as her applications of multi-sensory materials to individualise her work with each of her students. Her experimenting with stories and visual materials to enhance perceptions, as well as her finger exercises to enhance motions in the elementary stages of learning has been investigated for this study to explain her processes and solutions for learning technical violin skills.

Hendrickson's solutions to advance techniques in elementary studies could be trialled and researched in future studies. In particular using her understanding of learning processes in the transfers of patterns, and the design of a varied multi-sensory program individually tailored for each student.

Whilst the findings of this research suggests that Hendrickson's individualised violin exercises accelerated her student's technical abilities it does not account for learning support X may have had outside of lessons with Hendrickson or what they may have learned prior to studying with Hendrickson. While there are no recordings available of X performing the Mendelssohn concerto during the period covered in X's file, an archived cassette recording exists in the Hendrickson Estate of an accomplished X performing the second and third movement of Mendelssohn's *Violin Concerto* at a competition in Adelaide at the age of eleven. Another cassette tape contains a recording of an Australian Broadcasting Commission broadcast with an outstanding performance

of the entire concerto with 19-year-old X as a soloist. Like numerous other Hendrickson students, X went on to have a distinguished career as a professional violinist. Due to the approved ethics protocol for this study for privacy reasons, access to these archived recordings remains embargoed until such time that they may be released with permission.

Future research and funding will be needed to examine and report on all of Hendrickson's individualised teaching files to provide in greater detail her pedagogical framework, use of scientific theories and contribution into music didactics. There are several thousand or so other exercises files from the Hendrickson Estate Archive for example that as yet have not been perused for this study. These exercises may provide future instrumental teachers with Hendrickson's blueprints for a greater understanding of the transfer of elements and patterns in skill acquisition.

As a young performer Hendrickson was aware of somatosensory feedback and learning violin skills from multi-sensory pathways (Alberti, 1994). In her recovery from polio, Hendrickson's awareness of sensory learning and motor functions was enhanced by her attentions to patterns of exercises that that ascended the G string (Hendrickson, ca. 1980). Sliman Bensmaia from the Department of Organismal Biology and Anatomy at the University of Chicago studied the role of somatosensory neuroprosthesis and the signals from sensors on prosthetic hands. In 2015 he wrote, "We know that without somatosensory feedback the motion of any prosthesis is clumsy. With an abled person with no prosthesis the same applies in the learning of any skill ... Indeed, in individuals with intact arms and motor pathways, but without somatosensory feedback, movements are slow, clumsy and effortful" (Bensmaia, 2015, pp. 5–6). From the mid 1960s Hendrickson sought to optimise attentions to somatosensory feedback through her experimental exercises for her students to transfer the left-hand into other position from the first elementary violin lessons. In executing finger-stopped notations the learner must calculate depths of weight and pressure in both the right and left-hand motions to play every sound. This is also partly due to the strings being strung at increasing incremental heights from the nut to the bridge over the fingerboard. Hendrickson's strategies for not limiting motions and allowing student X to access to the entire length of the fingerboard from the first few lessons, encouraged the early perceptions of transfers and mapping of motions from somatosensory feedback.

7. Conclusion

Although Hendrickson was clearly aware of existing, conventional violin pedagogy, this study shows her approach to teaching the violin was pioneering in its time (RQ 4). Her experience of rehabilitation from paralysis due to contracting poliomyelitis in the 1950s, and further study of neuroscience and learning psychology, influenced this process (RQ1). The discussion of X's file shows some of the processes she used to compose her own, individualised violin exercises to enhance her students' skill acquisition, applying her understanding of theories of transfer (Thorndike & Woodworth, 1901), human performance theory, redundancy, and somatosensory and multisensory learning (Marteniuk, 1976; Wickens, 1984) (RQ2 and 3).

This study of X's file shows that X progressed from the elementary stages of learning to advanced drills and repertoire, only three years after beginning lessons with Hendrickson. X's exercises that encompassed the transfer of somatosensory awareness to all parts of the fingerboard, as well as right-hand motions that achieved early introduction of elements of advanced bowing techniques was a departure from traditional violin teaching methods at the time. Hendrickson's technical solutions for X illustrate her ability to tailor exercises to her pupils' individual abilities and to target specific aspects of left- and right-hand techniques required when performing a piece. Her drills target specific elements of left- and right-hand techniques for her students to form a somatosensorial image and memorization of motions.

The color, imagery, humor, and stories from X's file demonstrate how Hendrickson's originality and creativity enhanced her student's violin learning and motivated this young student to comprehend and carry out set tasks. X's file illustrates that by the mid-1970s, Hendrickson had developed an educational approach that was new at the time, in teaching beginners' new skills in

different positions on the fingerboard and employing transfers to assist their somatosensory learning of patterns and sequences in both the left- and right-hand violin-playing motions (RQ4).

In the 20th and 21st centuries, investigations have found that neuroplasticity changes may occur in musicians' brains from learning or playing musical instruments. Elbert et al. (1995) found large representations and reorganizations of the primary somatosensory cortex from their study of violinists' left-hand fingers. Continual plasticity and recovery of the central nervous system circuitry was associated with new learning. Knecht et al. (1998) found that several human subjects who had arm amputations demonstrated metaplastic reorganizations and accompanying changes in the patterns of their sensory processing. Although Hendrickson did not have her left arm amputated, her paralysis and consequential loss of motor control followed by new learning in her recovery process suggests that she too experienced metaplastic reorganizations and alterations in her patterns of somatosensory processing. Her ability, to transfer insights from this life experience using violin exercises tailored to her individual students' needs, to promote their sensorimotor learning exhibits a novel pedagogical approach that deserves recognition. Future research into Hendrickson's other exercises and student files may result in further understanding in her sequenced motor-skill learning on the violin, and the processes she used to enhance her students' learning through her individualised, multisensory pedagogical approach.

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