Score Your Way to Clinical Reasoning Excellence: SCALENEo Online Serious Game in Physiotherapy Education

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Abstract

We present an online serious game aiming at improving clinical reasoning in musculo-skeletal physiotherapy. The serious game is based on the "Happy Families" card game, in which a clinical case is analyzed by a group of players through cards representing families of clinical hypotheses. The SCALENEo (Smart ClinicAL rEasoning iN physiothErapy) project is the online version of the "Happy families" card game. Since it allows for students to play alone or in group without the supervision of a teacher, we propose a way to assess clinical reasoning via a feedback in two steps: A system of green/yellow/red flags giving a card-by-card feedback, and a global score measuring the agreement between the played game and a reference game. We find that the proposed way of scoring a played game favours cautious players, i.e. players who chose not to answer rather than giving a random answer. Also, our score is only rewarding (well above 50%) when players reach a percentage of errors lower than 50%, which is a way of enforcing a correct knowledge of the families of hypotheses before analysing a clinical case.

Introduction

Learning clinical reasoning (CR) is an integral component of physiotherapy education (Schuwirth, 2009) and professional practice, directly influencing decision-making processes crucial for effective and safe patient care. CR encompasses a range of analytical and non-analytical processes and skills used in patient assessment and management, involving both the development of hypotheses and pattern recognition (Croskerry, 2009a, 2009b; Jones, 1992). For physiotherapy students, mastering hypothetico-deductive analytical reasoning - involving generating and testing multiple hypotheses - is essential due to the diverse and complex nature of patient presentations (Bowen, 2006; Jones, 1992; Jones, 2019; Rivett, 2004).

The importance of employing different categories of hypotheses (Jones, 2019), also known as families of hypotheses (Hage, 2023), is well-documented in the reflective practices of experienced clinicians and educators (Barlow, 2012; Edwards, 2004; Jones, 2019; Rushton, 2016; Smart & Doody, 2007). This approach enhances the consistency of clinical judgments considered while promoting thoroughness in clinical reasoning.

In educational settings, a variety of tools and methods are needed to accommodate the diverse profiles and skills of students. One promising approach is gamification, which can enhance learning engagement and cooperation by applying real-world scenarios (Krishnamurthy, 2022). Specifically, serious games (SG), a type of game-based learning aimed at achieving specific educational outcomes (Gorbanev, 2018; Haoran, 2019), has shown efficacy in improving concentration and knowledge retention among learners (García-Redondo, 2019; Gorbanev, 2018; Tubelo, 2019). CR learning through SG (Blanié, 2020; Koivisto, 2018) and online simulation games (Cant, 2010; Lapkin, 2010) has already been used with positive feedback in nursing training.

The integration of SG in nursing (Koivisto, 2018) and medical education (Tubelo, 2019) has yielded positive outcomes (Qiao et al., 2023). Inspired by these successes, we extended the use of SG learning to physiotherapy education through the “Happy Families” card game (Hage, 2022; 2023). This card game appears to be a promising tool for engaging students in learning CR and improving their awareness of cognitive biases and reflective practice. The SG “Happy Families” primarily focuses on cognitive bias processes through manipulation in a hypothetico-deductive construction of CR at the start of patient analysis, and it applies a socio-constructivist approach to learning through the exchange of ideas between game partners. At the start of the game, players (i.e. students) are provided with a fully detailed clinical case including both quantitative and qualitative data. The game includes a set of cards representing the "Hypothesis Families": core categories of clinical judgment such as patient’s expectations, pain, origin of symptoms etc, see Hage et al. (2022) for a full explanation of these families. The students must then select the cards where they have initial hypotheses and, using a erasable pen, write a list of the hypotheses on the back of the card. In addition, a “Wild card” is provided for players to write the main hypotheses (first choice at this stage) in each family. The game then proceeds as follows: once all the hypotheses have been written down, and in agreement with the teacher, the players can present their game to the other groups of players to justify and compare their choices.

Beyond SG, technology-enhanced learning is increasingly recognized as a vital tool for improving both education and continuing professional development, which are essential for ensuring high-quality healthcare services. The positive impact of using virtual scenarios as learning activities on outcomes such as knowledge acquisition and CR has been well-established in medicine. These technological methods can be described as "interactive computer simulations based on clinical scenario cases". In a 2019 systematic review and meta-analysis assessing the effectiveness of virtual patients compared to traditional teaching, Kononowicz et al. (2019) found that using virtual patients improved or equaled traditional education in terms of clinical reasoning, procedural skills, and a combination of procedural and team skills.

The Erasmus+ "SCALENEo" (Smart ClinicAL rEasoning iN physiothErapy) https://scaleneo.eu aims to promote the SG “Happy Families” through an online approach. The aim is to leverage the possibilities offered by information and communication technologies to develop an online version of the Happy Families SG to reach geographically remote and emerging audiences and, mostly, to allow individual players, i.e. students or physiotherapists wishing for self-training their CR. The online implementation of our SG leads to a key question which is at the heart of our present study: How to provide relevant feedback about one player’s CR? Similar to test-enhanced learning (Roediger, 2006), it is indeed crucial to evaluate students and to provide feedback on the quality of their work and their progress in learning CR. The 'Happy Families' game will also serve as a formative assessment tool, provided that an answer is given to the preceding question.

The value of student assessment is well established (Larsen, 2008). CR skills are particularly challenging to assess because they encompass a combination of cognitive abilities required to analyze and synthesize problems (Min Simpkins, 2019). Research in cognitive psychology indicates that the use of tests can enhance information retention (Larsen, 2008). Evaluating CR, which stems from complex internal cognitive processes that are not directly observable, is inherently problematic. CR involves the integration of cognitive, psychomotor, and affective skills (Huhn, 2019), necessitating a flexible assessment procedure. The term CR encompasses various skills including decision-making, critical thinking, problem-solving, clinical judgment, and diagnostic reasoning (Young, 2019). Therefore, it is through these terms that we must identify and assess the relevant skills that will eventually lead to a global score.

Despite the demonstrated benefits of SG in nursing and medicine fields, there is a notable lack of research on the use of such tools for assessing and enhancing CR in physiotherapy. More, in the medical field, there is no gold standard for assessing CR (Simpkins, 2019) and this is also true in physiotherapy, highlighting a significant gap in the literature. Current assessment methods in medical education, such as the Assessment of Reasoning Tool (Thammasitboon, 2018), the Think Aloud protocols (Pinnock, 2015) and the Script Concordance Test (SCT) (Charlin, 2000) have been proposed. Specifically, the SCT method has been used since the work of Charlin et al. (2000). The SCT is based on script theory and involves comparing students' interpretation of clinical data with those of experienced clinicians through a series of clinical tasks presented in specific and "ill-defined" contexts. In summary, an ill-defined case is presented to candidates as a brief clinical scenario where the information provided is insufficient to make a definitive decision. In addition, data provided by motion capture systems are integrated to the scenario to improve their integration in the participant initial clinical reasoning process. Thus, biomechanical data that illustrate the clinical case in the manner of a paraclinical examination are presented in connection with the clinical case. The objective is to enrich the participant's reasoning with data from the contribution of technologies for rehabilitation, which are now part of an ecosystem that is increasingly present in clinical practice. Each case is followed by several questions that begin with a hypothesis, followed by additional information. Participants are then asked to assess how this new information impacts the likelihood of the proposed hypothesis being correct (Brentnall, 2022; Charlin, 2000; Dory, 2012, 2016).

Since the SCT method has proved reliable and effective for measuring CR in health professions such as nursing (Deschênes, 2011), medicine (Cohen Aubart, 2021) and physiotherapy (Kojich, 2024; O'Brien, 2023), the aim of this study was therefore to show if an adaptation of SCT is feasible for testing physiotherapy CR during the "Happy Families. As in the original SCT, the hypotheses will have to be confirmed or refuted, but in our game the players will have to highlight the additional information provided in the description of the clinical case. The players are then asked to assess the impact of the information on the probability that the hypotheses proposed are correct. By integrating the adaptation of the SCT in an online version of the "Happy Families" card game, we aim to enhance the quality of CR training and ultimately improve patient physiotherapy care outcomes.

Method

We will first show how the SG looks and is played online; we refer the reader to the website https://scaleneo.eu/en/home-english/ for an actual use of the SG. Then we will show the technical details allowing to understand the feedback provided.

Online game

The game starts when a player or a group of player selects a given clinical case, the clinical cases being labelled by the pain localization. The player(s) then read the clinical case, mostly composed of text and kinematic plots. Pre-selected groups of words or elements can be selected and assigned to one or more hypothesis families in the form of a card (Fig. 1). This first phase of the game is therefore the hypothetico-deductive reflection on the clinical case and the selection and linking of elements of information to the hypothesis family or families the student(s) judge they inform.

During the game, a chat is enabled to allow for discussion in the case of multiplayer game. Players are allowed to consult their courses or any relevant source of information – articles published in peer-reviewed journals are also suggested in the clinical cases.

When the player(s) has/have ended his.her/their analysis, all selections and assignments are made, a blue button on the right corner of the screen can be clicked and triggers the display of the results (Fig. 2A). At this stage it is crucial to say that all the results are obtained by comparison to a reference game, i.e. an "ideal game" as established by consensus by the partners of SCALENEo. Figure 2 displays the feedback procedure. The first feedback (Fig. 2B) is a hypothesis-by-hypothesis count of the information correctly assigned by the player(s). A green/orange/red flag (be careful not to be confused with the notion of red flag used in clinical practice) is related to the percentage of items correctly assigned (high/medium/poor) and to the correct identification of crucial information, see below. Figure 2C finally shows a global appreciation under the form of a gold/silver/bronze brain and of a total score. Three difficulty levels are implemented, giving the player(s) the possibility the make several attempts before the definitive feedback: easy is 3 attempts, medium is 2 and hard is 1. The brain level is calculated according to the number of attempts needed to eliminate all the red flags: first attempt, gold, second attempt, silver, third attempt, bronze.

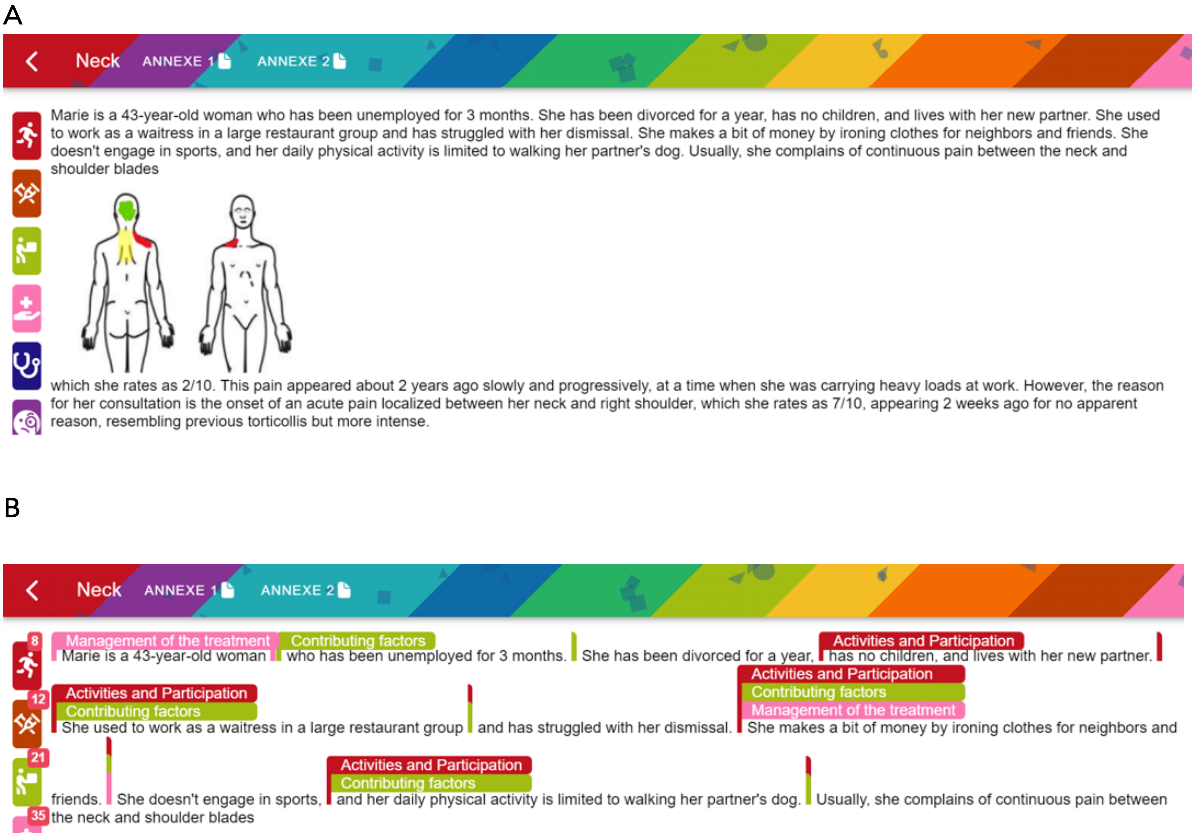


Figure 1. Screenshots of a neck-pain clinical case. The clinical case is displayed before assignments of the information to hypothesis families (A) and after (B).

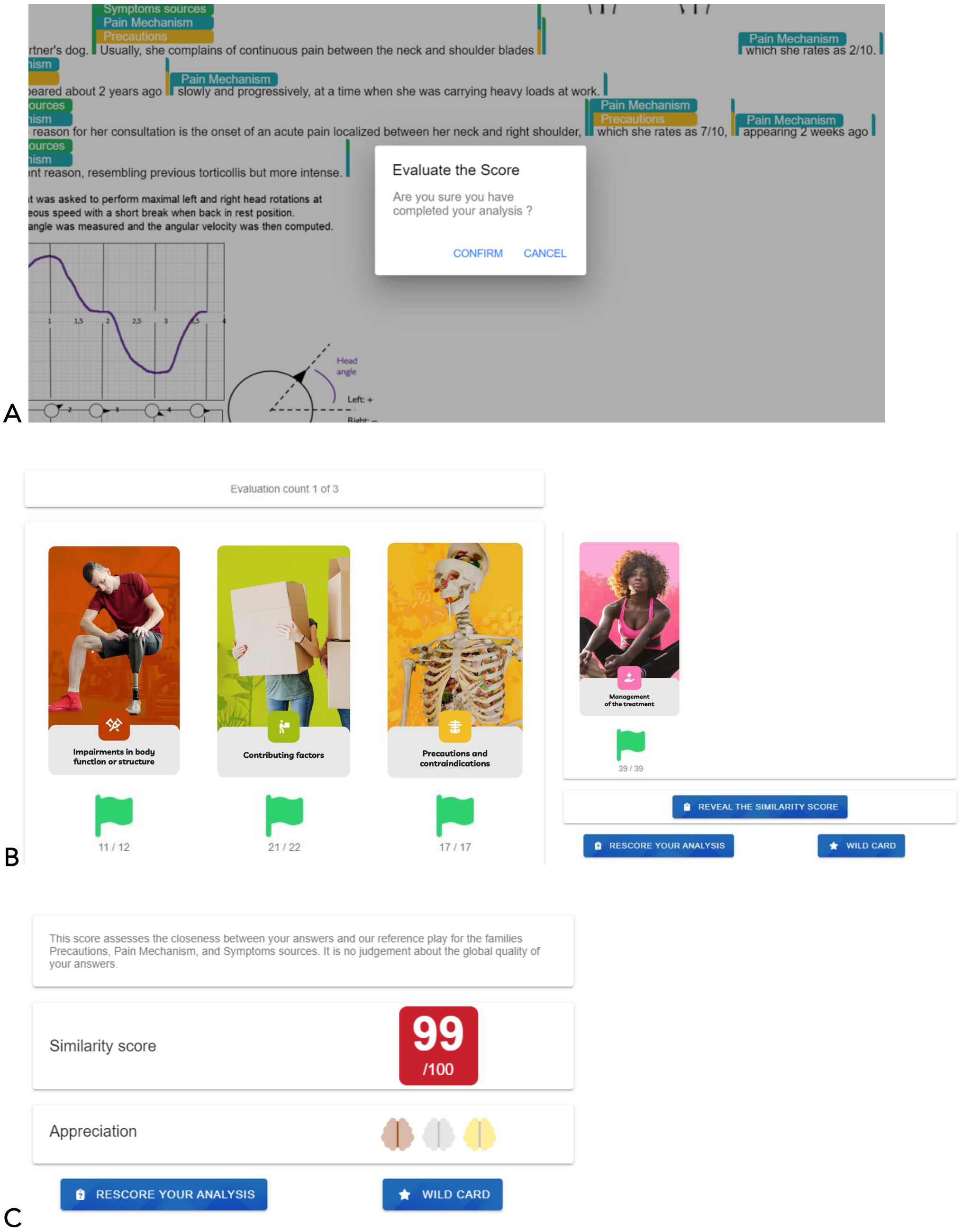
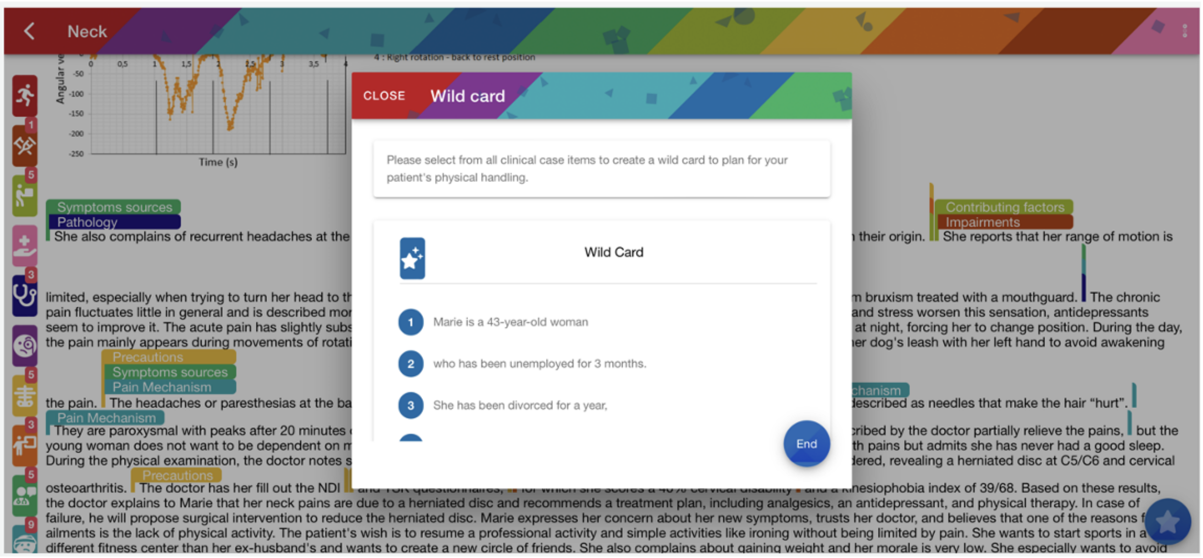
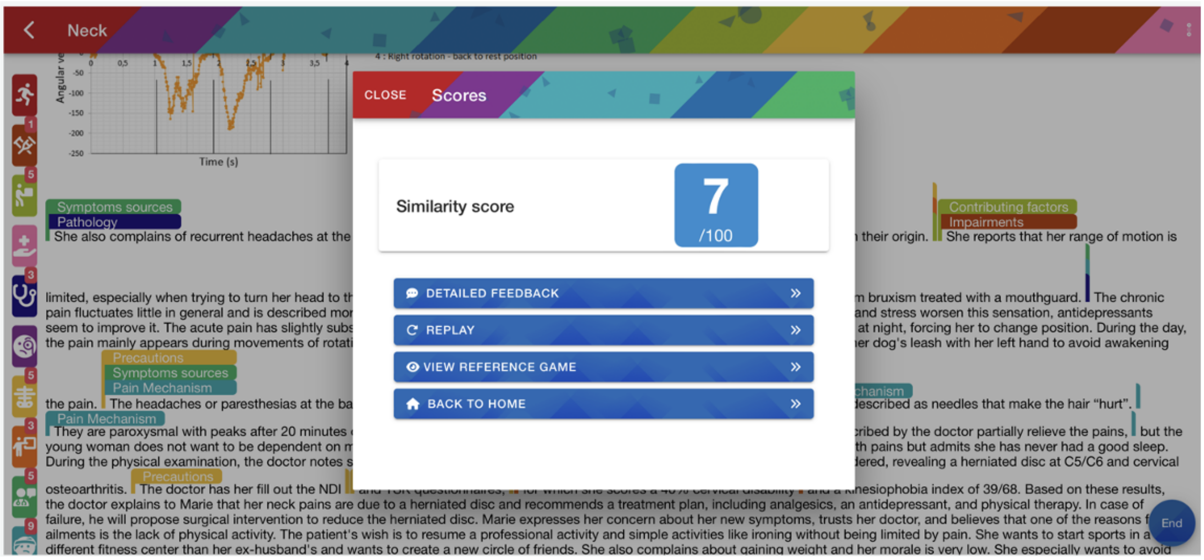


Figure 2. A: End of a game and beginning of the assessment procedure. B: Hypothesis-by-hypothesis assessment; counting of the number of elements correctly assigned by the player(s). C: The score is revealed with a warning message and a global appreciation under the form of a gold/silver/bronze brain.

At the end of all attempts, a wild card must be selected (Fig. 3A). The latter card is the one containing the most important information about the clinical case presented according to the player(s). A final score is then computed.



A



B

Figure 3. A: Selection of the wild card. B: Final feedback.

After the choice of the wild card, the final feedback is displayed (Fig. 3B): It consists of an overall score (this time considering the special card) and of all the other elements mentioned above. At this stage it is also possible to look at the reference game.

Classifying card elements

We now turn to the technical points "hidden" behind the online game; these points are actually a key part of the novel approach we propose to assess CR. When an element of information (an item) is selected by the player(s), features are assigned to it, as it can be seen in Tables 1 and 2.

Table 1: Categories to which one element of information (one item) selected by the player(s) can belong. "Good" means that the item has been assigned to the correct hypothesis family. "Relevant" means that means that the information is consistent. "Crucial" means that the information is considered as essential by experts in the reference game (e.g. red flags). "Bad" denotes a relevant item but not assigned to the hypothesis family. "Wrong" means an item that is considered by the player(s) but not in the reference game. "Missed" means an item that is considered by experts but not by players. "Empty" is an item that is not chosen by both player(s) and the reference game.

Categories	Presence of the element		Type of the element		Item ID
	Reference card	Game card	Reference card	Game card	
Good relevant item	Yes	Yes	Relevant	Relevant	1
Good crucial item	Yes	Yes	Crucial	Crucial	2
Bad relevant item	Yes	Yes	Relevant	Crucial	3
Bad crucial item	Yes	Yes	Crucial	Relevant	4
Wrong relevant item	No	Yes		Relevant	5
Wrong crucial item	No	Yes		Crucial	6
Missed relevant item	Yes	No	Relevant		7
Missed crucial item	Yes	No	Crucial		8
Empty item	No	No			9

Table 2: Schematic view of one element's categorization according to its presence or not in a game card.

		Reference card	
		Present	Not present
Game card	Present	good	wrong/bad
	Not present	missed	empty

A played game therefore consists in a set of selected items by the player(s), the game cards, that must be compared to the reference cards, i.e. the cards filled by the SCALENEo experts.

Flags and thresholds

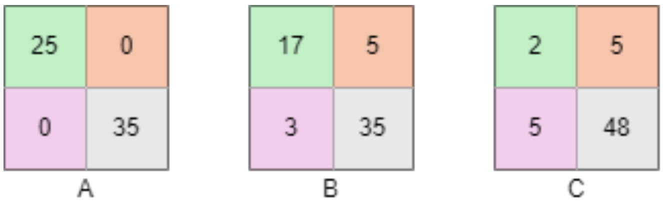
After comparison between reference and game cards, the flags are displayed. Their color is:

- Red if crucial elements have been missed or marked as relevant where it is not. We then recover the notion of red flag used in clinical practice (we use the term "notion" because the information noted as red flags may not be the same as that known as such in the literature).
- Green if the game and reference cards are either both empty or if all the crucial elements are found and more the 50% of the reference card elements are correctly identified. This threshold of 50% is a parameter and could be lowered of increased according to the player(s) experience for example.
- Yellow if all the crucial elements are found and the percentage of correctly identified items is below the threshold of 50%.

Total score

The total score is computed from individual card score. These are calculated using a Cohen's Kappa coefficient measuring the agreement between game and reference cards according to the selected items (category and number). Recall that Cohen's Kappa measures the degree of agreement between two observers; in our case the game and reference cards are seen as two independent observers whose agreement can be measured. Cohen's Kappa is finally multiplied by 100 to have a card score between 0 and 100. Note that if a card in the reference game is empty and the corresponding card in the game played is also empty, the score is defined to be 100%, because the two observers agree not to put any elements in the cards. Figure 4 displays 3 examples of card score calculations.

Figure 4. Examples of distribution of elements in a card according to the classification described in Table 2. A: Only good items present in both cards, leads to a score of 100%. B: Some missed or wrong items are present; this example leads to score of 71%. C: This example leads to a score of 19 %, because of low number of good items.



The total score is defined as the average card score between the 3 following families: type of pain, sources of symptoms, precautions and contraindications. This reflects the most important categories among the hypothesis families in the musculo-skeletal domain. The total score is updated after the last attempt and is now the average score between the 3 above families and the wild card score.

Score evolution vs number of errors

We have chosen the following procedure to assess our way of scoring a game. First, using a developer tool in the online application, game samples were generated by duplicating one clinical case's reference game (neck pain patient), and then by introducing errors by randomly removing a given percentage (*n*) of items. 20 samples for each value of *n* were generated with $n = 0, 5, 10, \ldots, 100$ %. Second, the same procedure was applied but items were randomly replaced by a random item instead of being removed. A total of 840 plays has therefore been generated. In both cases, at a given *n*, interpreted as the % of errors, the average score and its standard deviation were computed for a single attempt, i.e. no wild card effect has been added. Then, the rate of decrease of the score was computed as the derivative of the score as a function of *n*. The games with removed items are interpreted as representative of a "cautious player", i.e. a player preferring not to answer when he/she is not certain of the answer. The games with replaced items are interpreted as representative of a "bold player", i.e. a player taking the risk of answering to items of which they are not fully sure.

Results

The evolution of the average score versus the percentage of error is displayed in Fig. 5, where it can be seen that the scores with replaced items are always lower than with removed items at a given percentage of error: The bold player has always a lower score than the cautious one in our approach.

The score decrease rate versus the percentage of error is displayed in Fig. 6. It can be seen that the score is not very sensitive to the % of error if the latter is small for a cautious player. Both cautious and bold payers' scores are strongly impacted by the % of error as soon as the latter is larger than about 25 %. The numerical values are given in Tables A1 and A2 for completeness.

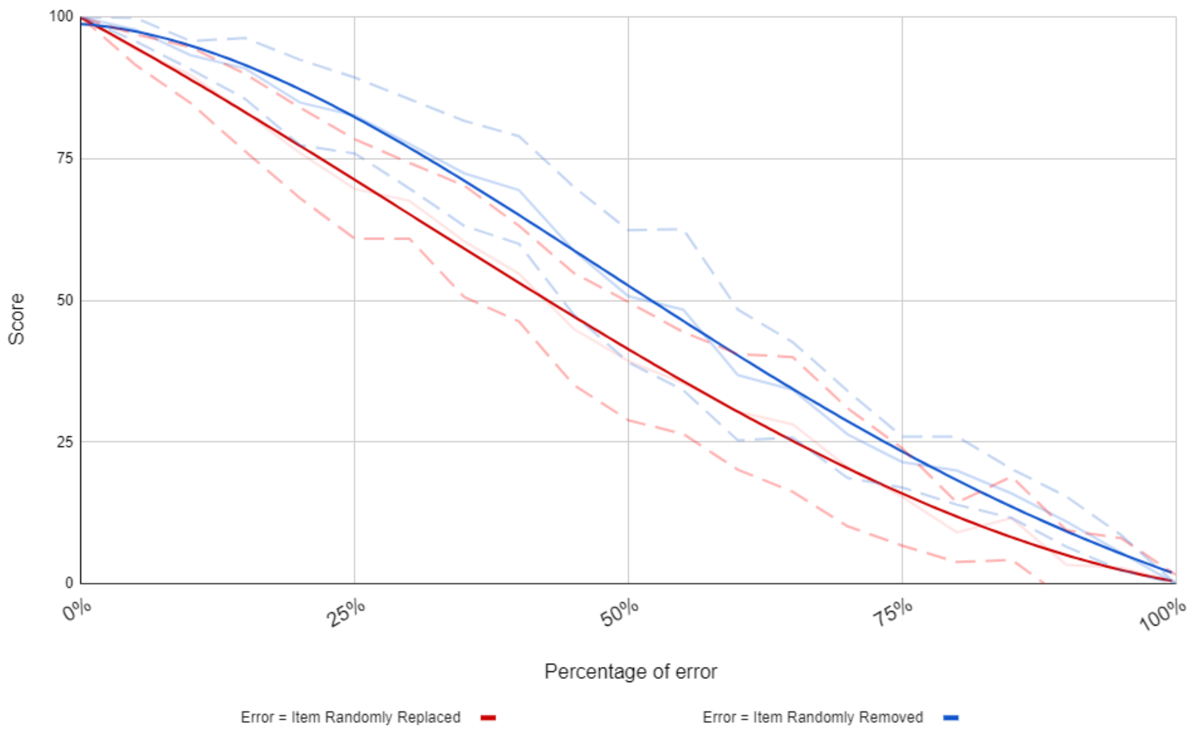


Figure 5. Evolution of the averaged scores (computed on 20 plays) versus the percentage of error. The blue line shows the generated plays with removed items, and the red line shows the generated plays with replaced items. The dashed lines define an interval of ± 1 standard deviation around the average scores. The blue and red lines show a fourth-order regression line of the averaged scores to better guide the eyes. They have equations Score = 98.8 – 14.1 x – 266 x^2 + 254 x^3 – 71.1 x^4 and Score = 99.9 – 104 x – 58.1 x^2 + 65.3 x^3 – 2.8 x^4 respectively, with x = Percentage of error.

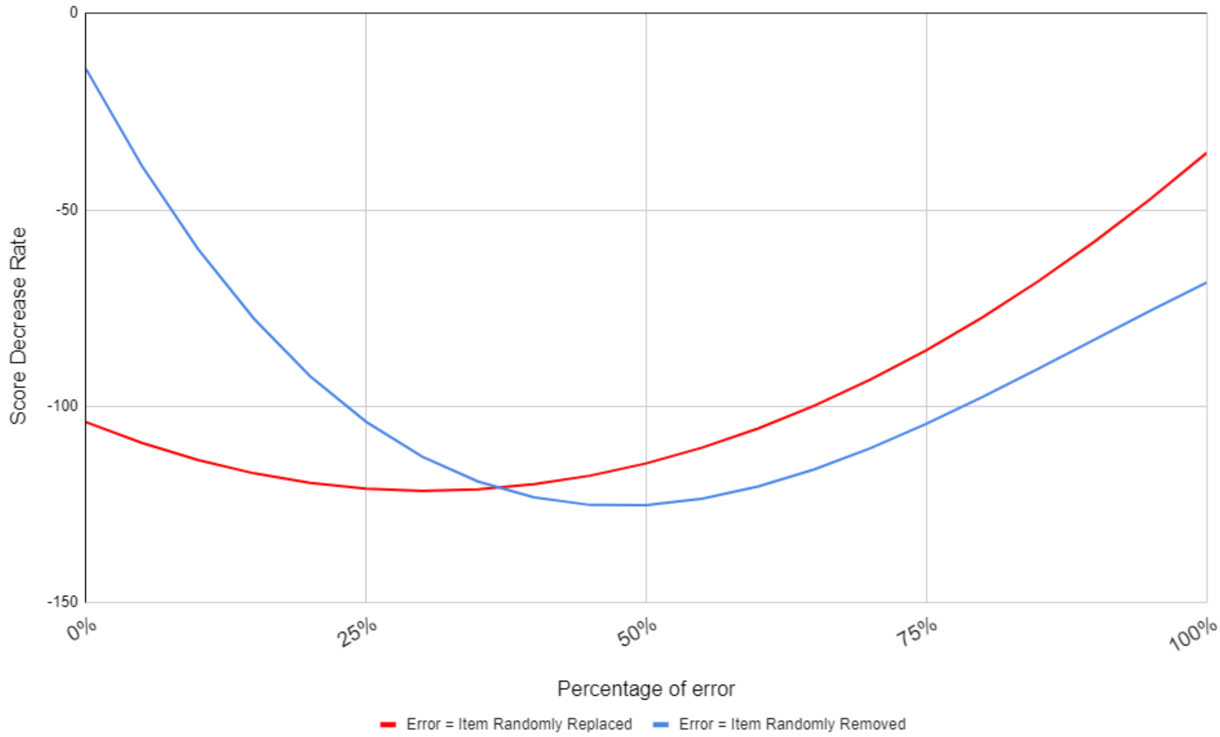


Figure 6. Same as Fig. 5 for the score decrease rate.

Discussion

As stated before, our SG shares similarities with SCT. In SCT, participants assess a clinical situation using limited information, after which additional information is introduced to reassess their previous choices. These are then evaluated against expert judgments (Dory et al. 2016, Charlin et al. 2000). Conversely, in SCALENEo, players must identify and categorize information from a comprehensive clinical case presented upfront. This difference highlights the game's potential to actively engage learners in exploring and justifying their reasoning processes, as well as enhancing their ability to navigate ill-defined scenarios, a critical aspect of CR (Croskerry, 2009b). In our clinical cases, each card can be considered as a "case" that will need to be nuanced according to each family of hypotheses. That is why the first feedback we provide is the collection of flags, displayed card-by-card. This aims at showing the student(s) whose hypotheses families they understand satisfactorily or poorly. The red flags are clearly identified as needed in a SG preparing students to clinical practice. The integration of card-by-card feedback aligns with prior research emphasizing the value of formative assessment in CR education (Larsen, 2008). Immediate, targeted feedback allows learners to identify cognitive gaps and improve iteratively, promoting deeper understanding and reflective practice. This approach mirrors the structured feedback mechanisms in SCT but innovates by embedding it in an engaging gamified format. Gamification, as highlighted by Koivisto et al. (2018), provides principles for designing educational tools that enhance engagement and learning outcomes. SCALENEo leverages these principles effectively, fostering motivation and active participation among learners.

Our results demonstrate the value of scoring as a secondary, rather than primary, feedback mechanism. While scoring is not central in face-to-face sessions led by expert teachers, it is essential for unsupervised play in SCALENEo. The game’s cautious-first scoring system rewards deliberate and reflective decision-making, favoring players who prioritize accuracy over risk-taking. This approach aligns with educational theories that emphasize the importance of careful hypothesis testing (Larsen et al., 2008) and the mitigation of cognitive biases in clinical judgment (Croskerry, 2009b). It is particularly suited for intermediate learners who possess foundational knowledge of hypothesis families and are ready to refine their skills further.

The study of score evolution versus error rates underscores the importance of preliminary instruction in hypothesis families. The quick increase in scores for players with error rates below 50% suggests that SCALENEo is most effective when integrated into a broader curriculum with pre-game theoretical modules. This structured preparation ensures learners can engage meaningfully with the game's content, supporting both knowledge retention and skill application (Gorbanev et al., 2018).

Despite its strengths, certain limitations of our scoring method of the SCALENEo game must be acknowledged. The reliance on expert-defined reference games assumes homogeneity in CR, potentially overlooking variations in reasoning styles or regional practice differences. Future developments could explore adaptive feedback and dynamic difficulty adjustments to make the game more inclusive for novice learners while maintaining its value for intermediate and advanced users. Incorporating design principles from Koivisto et al. (2018) could further refine the game's accessibility and adaptability.

Additionally, the online platform offers significant opportunities for research. Anonymized gameplay data could enable large-scale analyses of CR patterns across different demographics and educational backgrounds. Such insights could guide targeted instructional material development and address gaps in existing curricula. For example, differences in reasoning approaches between novices and experts, as outlined by Croskerry (2009b), could inform personalized feedback mechanisms in SCALENEo.

Lastly, SCALENEo’s gamified approach has broader implications beyond musculoskeletal physiotherapy. By adapting the game to other domains, such as neurological or pediatric physiotherapy, its benefits could be extended to a wider range of learners. This scalability highlights its potential as a transformative tool in healthcare education. Furthermore, its emphasis on mitigating cognitive biases and encouraging cautious decision-making underscores its alignment with the principles of safe and effective patient care (Croskerry, 2009b).

In conclusion, our scoring method of the SCALENEo game combines the strengths of serious games with the rigor of established CR assessment methods. Its innovative approach to formative feedback, combined with an engaging and accessible online platform, positions it as a valuable tool for improving CR skills in physiotherapy education. By addressing cognitive biases, leveraging gamification principles, and integrating adaptive feedback, SCALENEo bridges the gap between knowledge and application in a way that traditional methods often fail to achieve.

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Appendix: Numerical values of the results

Table A1. Numerical results obtained in the case where items were randomly removed. Average score (of 20 generated games) are given with their standard deviation. The last two columns give the minimal and maximal scores that were generated.

Error (%)	Average Score	Score standard deviation	Min	Max
0	100	0	100	100
5	97.80	2.07	93	100
10	93.30	2.47	88	97
15	90.95	5.38	76	99
20	84.95	7.54	65	94
25	82.65	6.70	63	91
30	77.65	7.88	63	93
35	72.45	9.26	53	89
40	69.50	9.49	49	88
45	58.80	11.28	27	75
50	50.75	11.65	33	75
55	48.40	14.20	25	73
60	36.85	11.54	18	60
65	34.25	8.42	21	47
70	26.40	7.69	10	43
75	21.50	4.49	15	33
80	20	6.01	10	35
85	15.95	4.33	10	25
90	11	4.42	0	16
95	5.50	3.10	0	8
100	0	0	0	0

Table A2. Same as Table A1 in the case where items were randomly replaced.

Error (%)	Average Score	Score standard deviation	Min	Max
0	100	0	100	100
5	94.25	2.71	89	99
10	89.80	4.94	80	98
15	83.15	6.83	69	95
20	76.05	7.97	65	89
25	69.70	8.77	50	86
30	67.60	6.68	53	80
35	60.45	9.83	36	76
40	54.75	8.43	38	67
45	45.00	9.88	26	62
50	39.30	10.42	23	63
55	35.45	8.99	21	53
60	30.35	10.20	13	53
65	28.15	11.88	12	62
70	20.60	10.42	6	45
75	15.35	8.59	0	38
80	9.10	5.25	0	23
85	11.60	7.35	0	25
90	3.35	6.11	0	24
95	2.85	5.21	0	20
100	0.40	1.19	0	5