The representative design of combat shooting methodologies from an ecological dynamics perspective: A scoping review.

Authors:

Mr Jack Harry Bale[a]– ORCID ID - 0000-0003-3531-3691; j.bale@latrobe.edu.au

Dr Corey Perrett[a f] – ORCID ID - 0000-0002-0638-0978; c.perrett@latrobe.edu.au

Prof. Keith Davids[b] – ORCID ID - 0000-0003-1398-6123; k.davids@shu.ac.uk

Prof. Jonathan Wheat[d] – ORCID ID - 0000-0002-1107-6452; jon.wheat@ntu.ac.uk

Ms Jemma Coleman[a c] – ORCID ID - 0000-0002-2957-2948; jemma.coleman@defence.gov.au

Dr Derek Panchuk[e] – ORCID ID - 0000-0002-1270-561X; derek@learntowin.com.au

Dr Kane Middleton[a] (Corresponding Author) – ORCID ID – 0000-0002-4914-8570; k.middleton@latrobe.edu.au

Affiliations:

[a] Sport, Performance, and Nutrition Research Group, School of Allied Health, Human Services and Sport, La Trobe University, Melbourne, Victoria, Australia

[b] School of Sport & Physical Activity, Sheffield Hallam University, Sheffield, United Kingdom.

[c] Defence, Science and Technology Group, Perth, Western Australia, Australia

[d] Sport, Health and Performance Enhancement Research Centre, Nottingham Trent University, Nottingham, UK

[e] Derek Panchuk, Chiron Performance, Canberra, ACT, Australia

[f] Kansas City Royals, Missouri, USA

Conflict of Interest Statement:

The authors have no relevant financial or non-financial interests to disclose.

Funding Statement:

This research was supported by a La Trobe University Full-Fee Research Scholarship (LTUFFRS). Additionally, this research was supported by Defence, Science and Technology group. No additional financial support was received for the preparation of this manuscript.

Word Count: 6688

i. Abstract

Combative military environments are ambiguous, uncertain, and dynamic, which certain tactical populations (military and law enforcement) must operate, whilst maintaining survivability by being mobile, situationally aware, and lethal. Training and performance evaluation, using the ecological dynamics framework, and constraints-led approach, can facilitate these operational requirements. This scoping review sought to investigate the representative design of combat shooting methodologies in the current body of literature. The search was conducted on SCOPUS, Military (ProQuest), Medline, and PubMed databases, providing 4450 articles for screening. Peer-reviewed articles (n = 105) were included for review, with populations including military, law enforcement, and cadets. The review concludes that methodological designs of combat shooting literature typically do not represent constraints of combat shooting contexts, rather implementing static designs, single-target engagements, pre-planned protocols, lack of friend-or-foe discrimination tasks, and limited use of temporal constraints. The validity of conclusions drawn in the combat shooting literature may be questioned for lacking action fidelity. Future studies could enhance skill transfer by including dynamic and multi-target engagements, unplanned protocols, friend-or-foe discrimination, and temporal constraints within training and assessment designs.

Key Words: Ecological Dynamics, Representative Design, Combat Shooting, Performance Uncertainty, Affordances.

1. Introduction

Combative military environments are convoluted, with considerable pressure to perform effectively in uncertain and often ambiguous settings, exacerbated by the asymmetric nature of modern warfare.[1] Clemente-Suárez and Robles-Pérez[1] characterise asymmetric conflict, predominant in modern combative military environments, as combat in urban areas, replete with civilians, carried out in an ill-defined battle zone. A key task in such military environments is combat shooting, undertaken at various distances to the target, involving attacking and defensive interactions between opposing groups, requiring the engagement and, often, neutralisation of an opposition force with a firearm. Combat shooting is typically conducted by tactical populations, a term employed in previous research to describe law enforcement and military personnel collectively.[2–4] Tactical populations include individuals with varying skill levels and technical competence in combat shooting, ranging from conventional military forces to special forces, or from a police officer to tactical (SWAT) teams. Increasing survivability of friendly forces within a combative military environment is paramount. Requirement for survival makes combat shooting different from other performance contexts, such as sport shooting, hunting, or marksmanship training (i.e., shooting statically at a static target a long distance away from the shooter, with a focus on deliberation, precision and accuracy),[5] in those settings, the shooter does not have an immediate threat to life greater than daily survival, creating a clear distinction between combat shooting and other shooting contexts. Busa et al.[6] split survivability into three sub-categories: situational awareness, mobility, and lethality. Situational awareness is required to perceive, identify, and distinguish threats ('friend-or-foe', number of targets and locations) within the environment. Mobility refers to a soldier's ability to acquire cover and locate targets quickly and effectively.[6,7]

Lethality is an operator's ability to neutralise an enemy target that poses a threat (e.g., their ability to shoot proficiently).[8] The environment in which tactical populations operate is typically ambiguous; therefore, research and practice in combat shooting must sample the surrounding informational constraints and ambiguities, (target types, location, identifying the need for friend-or-foe discrimination) when inferring an individual's level of survivability or the effects of an intervention on the components of survivability.

Ecological dynamics provides a theoretical framework for assessing how a performer meaningfully interacts with events, targets, objects, including other people, within such performance environments. These constraints are laden with information that can shape performance behaviours, providing a conceptual foundation to consider how coordination of actions in such complex adaptive systems emerges in context.[9] To explain the importance of sampling valid environmental information when assessing survivability, this review utilises the ecological dynamics framework, incorporating multiple conceptual areas, including ecological psychology, dynamical systems theory, and complexity sciences.[10] This conceptual framework aids understanding of motor coordination in the performer-environment system (e.g., combatant-battle zone). It provides insights on how an individual's actions emerge under interacting constraints in a combative environment (e.g., weather, visibility, terrain, locale, distances to targets, equipment, and presence of other combatants), continually shaping their adaptive actions and behaviours. To understand how coordination emerges, ecological dynamics integrates key concepts from Newell's model of interacting constraints,[11] representative design,[12] and affordances.[13] These key concepts underpin a viable framework for investigating how well studies and training tasks sample context-dependent constraints of performance environments within methodological design.

Constraints are characteristics that shape or channel a complex system's dynamics, either imposing limits or enabling the emergence of coordinated actions in biological movement systems.[9] Newell's *constraint-led approach*[11] differentiates three broad categories of constraints: environmental, individual, and task-related. Individual constraints are those specific to each performer, such as strength, hand-eye coordination, height, mass, emotional state, and previous experiences with a task.[14] Environmental constraints refer to physical properties of an environment (e.g., ambient lighting, altitude, weather, temperature) or the social world within which an individual operates (e.g., history, cultural norms, beliefs).[15] Last, task constraints are related to the specific demands of a performance context, including intended goals, locations, technologies, equipment and implements used, rules and boundaries.[16]

Ecological dynamics and the constraints-led approach aid in, not only evaluating emergent behaviours and movement coordination, but also supporting evaluation of research design and practice. Brunswik's *representative design*[12] concept provides methodological recommendations for designing testing and training environments when studying perception and action in coordination.[17] It advocates that research investigations should sample the information present in an individual's specific task and environmental performance contexts. Training environments are designed to improve the functionality of skill performance, a major component of which concerns adapting actions to the unfolding uncertainty of context. Conversely, testing environments try to understand the utility of a specific skill in completing the task goals of a specific performance context. Surrounding environmental information contextualises how individuals could adapt their goal-directed behaviours to meet performance demands. For this reason, there should be a close (representative) relationship between a test or training environment and the actual performance setting to support the transfer of learning, facilitating a close correspondence of action and behaviour between the two environments (termed '*action fidelity*').[18] Further, the perceptual information (specific structures of surrounding energy flows)[13] in a performance environment should also be available within a testing or training environment (termed '*information functionality*').[19] A lack of action fidelity and information functionality could result in the emergence of less effective movement strategies or degraded performance in learners.[20,21] For example, representative design implies that the technology and equipment used in practice should be *representative* (i.e., providing similar informational properties) of that found in a performance context, for example key information in the surroundings (e.g., contextualising the target for shooting). The equipment and technology should be used in the same way (live firing or a simulation that reflects the information and constraints of live firing). This means that body-worn equipment should be similar or reflect the constraints of actual occupational equipment and targets should be realistically scaled in an environment with representative terrain, cover, and opportunities for action (termed '*affordances*').[13]

Affordances are invariant environmental properties soliciting opportunities for action,[13] inviting functional coordination tendencies in a performer.[22] Affordances establish a direct link between the performer and the environment, where a performer perceives information for available affordances and acts in order to achieve their intended task goals. From a Gibsonian functionalist stance, a performer perceives information to continually engage with events, objects, substances, and places in which shooting occurs. These transactions provide context and information about the environment, guiding how a tactical population could act to achieve their intended task goals. Through practice and experience, perception and action become strongly coupled (directly linked), continually influencing each other.[13,23,24] How we engage with affordances influences how we learn, perceive, know, and decide how to act, but only if we have previously sampled information available within a performance context.[25] These key ideas on affordances imply that researchers and coaches must include relevant opportunities for action from a performance context in the training and assessment environment or risk a lack of information functionality and action fidelity.[18]

Temporal constraints govern the time available for perception and action on information specified by affordances in uncertain environments.[26] Consider a soldier locked into a dyad with an enemy combatant. The soldier will have to perceive affordances available within the environment, gather perceptual evidence about the 'friend-or-foe' nature of the target and coordinate movements to achieve the intended task outcome before the enemy combatant acts. In this way, the actions of an enemy combatant govern the time constraints acting on a soldier's survivability.[26] Temporal constraints guide visual search strategies and scanning behaviours used in specific contexts,[9,27,28] and shape the coordination dynamics of tactical populations', shaping lethality, mobility, and situational awareness.[6] Consequently, if the time to act is not constrained in combat shooting training and research methodologies, suboptimal behavioural tendencies may be developed or exhibited, resulting in low levels of action fidelity.[18]

Time to act is easier when there are fewer information sources to perceive, implying less *task ambiguity* in a performance landscape. Task ambiguity conceptualised in ecological dynamics relates to the nature of affordances available to each individual in a performance context.[29] Gibson[13] noted that "the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill." The implication is that the presence of an 'other' in the shooting context provides an affordance in the environment that offers different potential actions for an individual agent. In this way, the structure of the *affordance landscape* in a dynamic shooting context (e.g. targets) can increase the ambiguity of a perception-action coupling for a shooter, due to the potential for increased action possibilities.[29] 'Friend or foe' tasks in training environments increase the need to distinguish a target identity (providing *information uncertainty*) as the perceived target information implies different actions (shoot/don't shoot). In this way, the task becomes more ambiguous. Task ambiguity can also be increased if a combat shooter does not know the target locations within an environment and has to actively search for this information (*emergence of information*). This challenge could lead to unplanned training protocols requiring different perception-action couplings, compared to planned training protocols, in order to support the combat shooter in navigating the performance context in uncovering available affordances. Combative military environments can be full of ambiguity and uncertainty, so the nature of information within the combat and training environments is key to understanding the representative design of tasks for performance preparation in this context.[1]

Acting to perceive is critical to uncovering affordances within the environment, supporting the completion of task goals.[13,23] As tactical populations move around the environment in the time afforded to them, they can sample more information, increasing their possibilities for action.[29] Perceiving more information constrains a combat shooter's performance in ways that allow them to transition through the environment more successfully if attuned to information specifying affordances.[25] Since combat zones are ambiguous, uncertain environments,[1] tactical populations and enemy combatants must be dynamic (moving around the combat environment) to be successful. As such, mobility is critical to a survivability when engaged in combat shooting.[6] At the most basic level of evaluating the representative design of a training or research methodology for a combat context using ecological dynamics, determining the static-dynamic agent-target relationship is vital. The agent-target interaction is visualised in a two-by-two matrix where the agent and the target are categorised as static or dynamic (Figure 1) to characterise the nature of their relationship in the combat shooting literature. It is unlikely that in the combat shooting environment, both the agent and target will be static, unlike in marksmanship training tasks, conditions of which are often completely static (sniping or many sport shooting events). Nevertheless, marksmanship and combat shooting in the scientific literature are frequently intertwined with regards to performance demands, raising important questions about the similarities and differences between task constraints in these distinct performance environments.

[insert Figure 1.]

Figure 1. The agent-target behaviour metric.

Conducting a scoping review to report on the representative design of combat shooting literature will provide practitioners with an understanding of some potential deficiencies in current methodological designs. A preliminary search for existing scoping and systematic reviews was conducted on Google Scholar and SCOPUS on the 20th June 2023, revealing no similar reviews using an ecological dynamics framework to evaluate the representative design of combat shooting studies.

The primary aim of this review was to utilise an ecological dynamics perspective to evaluate the representative design of combat shooting performance assessment methodologies. To do this, the review examined the task constraints imposed on tactical populations in the combat shooting literature. The secondary aims of our analysis were to identify and quantify: (i) specific task constraints such as the static-dynamic agent-target interactions, (ii) the task ambiguity (affordance landscape, uncertainty of information, and emergence of information), and time to act (temporal constraint) incorporated into study designs, and (iii), the nature of equipment and targets used in existing research. This analysis will highlight gaps that need further investigation from an ecological dynamics perspective, perhaps guiding the representative design of future research methodologies in combat shooting.

1.1 Review Questions

1.1.1 Primary Question

- Framed by the ecological dynamics framework and the constraints-led approach, what individual, task, and environmental constraints have been used during combat shooting performance assessments?

1.1.2 Secondary Questions

- What static-dynamic, agent-target task constraints are employed when assessing combat shooting performance in combat shooting methodologies?
- Have studies investigated the ambiguity of target selection, and if so, how have they created ambiguous and uncertain environments for participants and constrained their time to perceive and act?
- What types of firing actions and targets are employed in the combat shooting literature, and do studies incorporate the representative constraints of body-worn equipment?

2. Inclusion Criteria

2.1 Types of Participants

Combat shooting tasks are usually performed by trained tactical populations, such as law enforcement officers, and military personnel (including special forces), under threat to life. As such, competition shooters and hunters were not included in this review as there is no threat to life or requirement for survival beyond daily life. The review included studies sampling participants at all skill levels, from special forces to regular militia, and police officers to tactical police units. The review also included cadets still in military or law enforcement training academies or universities, learning to perform in combat environments. This scoping review considered the representative design of methodologies used in the combat shooting literature, without the need to govern the selected participants' expertise levels. All studies included participants who required the assessment of survivability components previously identified to aid tactical populations in navigating their hazardous environments (situational awareness, mobility, lethality).[6]

2.2 Concept

This scoping review used the conceptualisation of an ecological dynamic's framework (e.g., static-dynamic agent-target interactions, constraints-led approach, representative design, perception-action coupling) to evaluate the representativeness of methodologies for assessing combat shooting performance and training. Outcomes of this analysis may aid future researchers in understanding the static-dynamic nature of combat shooting methodologies and performance contexts, the ambiguity and uncertainty of the designs of combat experiments, categorising which specific constraints have been imposed on tactical populations when assessing task performance and emergent coordination.

2.3 Context

Contexts of the scoping review comprised various performance environments and scenarios where combat shooting takes place, for example, shooting tasks embedded within law enforcement, military (armed forces, defence forces, special forces), paintball, airsoft, combat, and range shooting in real, simulated, or virtual environments. Studies were included in the review if they used a shooting task to assess combat shooting performance in any regard. The inclusion of paintball and airsoft contexts is due to sampling combat shooting environments, which sought to simulate the lethality of combat contexts; it is not ethical to use actual live ammunition when seeking to recreate actual combat scenarios.[30] The review incorporated multiple firing types, from live firing (shooting a projectile) to dry firing (not shooting a projectile) and simulated ammunition types (non-lethal projectiles).[31] This review also included marksmanship tasks undertaken by a combat shooting population, as marksmanship is heavily cited in the combat shooting literature.

2.4 Types of Sources of Evidence

This scoping review included primary source research, conference notes, and grey literature published in industry-specific journal reports, organisation databases and government departments. As research study methodologies are the concern of this scoping review, narrative, systematic, or meta-analyses were excluded.

3. Method

3.1 Protocol

This scoping review utilised the enhanced scoping review methodology framework of the Joanna Briggs Institute (JBI,[32] originally formulated by Arksey and O'Malley).[33] The JBI scoping review protocol constitutes nine stages for guiding a review. The nine stages were conducted in the following order: (i) defining and aligning the aim/s and question/s, (ii) creating and aligning the inclusion criteria to fulfil the aim/s and questions, (iii) formulating the planned approach to evidence searching, selection, data extraction, and presentation of evidence, (iv) conducting the evidence search, (v) selecting evidence, (vi) extraction of evidence, (vii) analysis of evidence, (viii) presentation of results, and (ix), summarising evidence in relation to the scoping review aims, making conclusions, and noting implications of the findings. This approach aligned with the Preferred Reporting Items for Systematic Reviews statement for scoping reviews (PRISMA-ScR) to promote methodological rigour during the review process.

3.2 Search Strategy

The participant, concept, and context (PCC) framework formulated search terms for the strategy behind this review.[34] The search algorithms comprised of AND and OR operators to couple search terms between and siphon search terms in the PCC framework. The structure of the search algorithm was as follows: (population OR population…) AND (concept OR concept…) AND (context OR context…). Wildcard symbols (i.e., *, #, ?) broadened the search to capture any variations of spellings and plurality within search terms. The search strategy had two parts: an initial search and a main evidence search. The initial limited search was conducted first using the SCOPUS and Military Database (ProQuest) to examine article titles, abstracts and keywords that categorise these articles to formulate a comprehensive list of search terms to capture relevant literature, allowing for the broadest search possible. The final search was conducted with the terms in *Table 1*. Main evidence searches for the scoping review were conducted across SCOPUS, Military Database (ProQuest), Medline, and PubMed using the refined search terms from the initial search. All included articles had to be in English as this is the only language spoken fluently by the research team.

Table 1. Final search PCC terms.

Key Terms (PCC)		
Concept 1 - Population	*Concept 2 - Concept*	*Concept 3 - Context*
Shooter*	Performance	"Law Enforcement"
Gunm?n	Proficiency	Military
Riflem?n	Complexity	"Special forces"
Shooting	Task	Paintball
Marksm?n	Constraint	Army
"Combat Shooter"	Coordination	"armed force*"
"Combat Operator"	Lethality	"Defen?e force*"
Warfighter	Lethal	Combat
	Survivability	Marksmanship
	Qualification	Simulate*
	Readiness	"Virtual Reality"
	Efficienc*	Airsoft
	Training	"Symmetric* Combat"
	Precision	"Asymmetric* Combat"
	Physical	Cadet*
	Measure*	
	Acquisition	
	Technique	
	Technical	
	Assessment	
	Evaluat*	
	"Skill level"	
	Assignment	

3.3 Sources of Evidence Selection & Screening

One author (JB) conducted a preliminary search and reported the results to the research team for consensus on the complete list of PCC search terms (Table 1). Then, once consensus was reached over the search terms to include in the main evidence search, the main search was performed. Two authors (JB & CP) performed the title and abstract screening and full-text review. The two authors (JB & CP) performed the initial stage of conflict resolution unless no agreement was made, and then a third reviewer (KM) mediated any conflicts, progressing an article to the next review stage. Only one article had to be mediated by a third reviewer at the full-text stage. Two authors (JB & CP) independently screened the articles at each stage before conducting conflict resolution to maximise methodological rigour.[32] Moving from one stage to the next in the review required consensus at every instance before moving on.

Articles from the final full-text screening were saved into a file and imported to Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia; www.covidence.org). The final database search was performed on 9th September 2024. Upon uploading articles to Covidence, duplicate articles were removed automatically.

3.4 Data Extraction and Analysis

Data extraction was performed in Covidence by creating a custom data extraction template (See supplementary material 1). Templated headings (e.g., population, concept, context) and subheadings (i.e., static-dynamic relationship, type of firing, targets used) were designed in response to our primary and secondary questions. Once the template was finalised, the first author extracted the data from each study in the review. Results were extracted from Covidence in a .CSV file and analysed in Microsoft Excel (Microsoft Corporation, 2018), creating frequency, percentage, and descriptive statistics.

4. Results

4.1 Search Results

The main search across the four databases returned 4450 articles; 1106 duplicates were removed, leaving 3344 articles for initial title and abstract screening. Title and abstract screening removed 3135 irrelevant articles, leaving 209 for the full-text review. An additional 104 studies were removed in the full-text review stage for multiple reasons (Figure 2); the three most common reasons were: 1) wrong population (e.g., participants did not require survivability beyond that of normal daily survival in their occupational context; n = 39), 2) wrong study design (e.g., not evaluating performance or training; n = 23), and 3) it was not possible to retrieve the full-text article (n = 22). Consequently, 105 articles were identified for the data extraction stage.

[insert Figure 2.]

Figure 2: PRISMA flow diagram of each stage of the search strategy and screening process.

4.2 Inclusion of sources of evidence

One hundred and five articles were included in this scoping review; all were peer-reviewed. This review included studies over five decades, from 1982 to 2023, with the most studies in the 2010s (n = 43), followed by 39 in the 2020s, 13 in the 2000s, 6 in the 1990s and 4 in the 1980s. The review encompasses articles from 22 countries, with the United States contributing most (n = 50), then Canada (n = 6), Netherlands and Spain (n = 5), Finland and Israel (n = 4), Belgium, Brazil, China, Czech Republic, Germany, Norway and Poland (n = 3), Iran (n = 2) and Australia, Croatia, Greece, South Korea, Sweden, Turkey, Ukraine, and the United Kingdom (n = 1).

The military population was the most frequently included demographic, with 73 studies (69.5%) including military personnel, 23 studies (21.9%) investigating law enforcement personnel and nine studies (8.6%) examining cadets.

4.3 Review Findings

4.3.1 What individual, task, and environmental constraints have been used during combat shooting performance assessments?

All studies, except one,[35] manipulated or observed the effects of constraints on combat shooting performance (*Table 2)*. 51.4% of all the studies included a task constraint, 54.3% included an individual constraint, and 13.3% included an environmental constraint. The most common constraints were those associated with equipment configuration (task constraints), training techniques (task and individual constraints), cognitive functions (individual constraints), fatigue (individual constraints), and load carriage (task constraints).

4.3.2 What static-dynamic, agent-target task constraints are employed when assessing combat shooting performance in combat shooting methodologies?

Fifty-nine studies (56.2%) implemented a methodological design with a static participant and static target when assessing shooting performance. Forty-two studies (40.0%) included at least one dynamic agent-target interaction. Static agent and dynamic target methods were used in 12 studies (11.4%), and dynamic agent and static target methods were used in 21 studies (20.0%). Nine studies (8.6%) used a dynamic agent and target method. The static-dynamic nature of four studies could not be discerned.

4.3.3 Have studies investigated the ambiguity of target selection, and if so, how have they created ambiguous and uncertain environments for participants and constrained their time to perceive and act?

Task ambiguity was assessed in four ways: number of targets presented in a single moment, investigation of planned and unplanned target selection in methodologies, whether a 'friend or foe' task was included, and use of temporal constraints (i.e., changes in time allowed to perceive an affordance and act); See *Table 2*. The proportion of studies including a task requiring target selection discrimination through a friend-or-foe task (shoot-don't-shoot) was 23.8%, a further 36.2% of studies had an unplanned protocol, and 23.8% of studies included more than one target presented in a single instance. Temporal constraints were included in 57.1% of articles in this review, with 29.5% including a *hard* temporal constraint, defined as one that could not be exceeded without task failure or consequence (i.e., a target is only presented for a prescribed amount of time). For studies with a hard temporal constraint, the average time to take a shot was 3.47 ± 3.24 s.

Table 2: Study breakdown of methodological constraints in the shooting assessment task.

Year	Author(s)	Target type	Number of targets presented in a single moment	Distance	Planned or unplanned target selection	Friend/foe task	Time constraint	Manipulated or observe constraint
1982	Haslam	Vigilance task: Silhouette Grouping task: Aiming point	1 1	100 – 300 m 100 m	Planned; Unplanned	No	5s per target No constraint	Individual
1983	Seppälä & Visakorpi	Silhouette	1	150 m	Planned	No	Shoot 1: No time limit Shoot 2: 5 s per shot.	Individual
1985	Schendel et al.	Weaponeer: Silhouette (E-type) Record firing: Silhouette (E & F-type)	1 1	100-250 m 50-300 m	Planned; Unplanned	No	Weaponeer: 100 m: 2 s; 250 m: 4 s Not defined.	Task, Environmental
1985	Sheeran	Not Defined	Not Defined	Not Defined	Planned	No	No Constraint	Individual
1994	Rice et al.	Not Defined	Not Defined	Not Defined	Planned	No	No Constraint	Task
1995	Vrij et al.	Simulated human	2	Not Defined	Unplanned	Yes	Shoot target before target shoots (target visible for 3 s)	Environmental
1997	Cheng-Kang & Yung-Hui	Silhouette	1	Simulated 100 m	Planned	No	Shoot as quickly as possible without sacrificing accuracy (No hard constraint).	Task
1997	Tharion et al.	Circular	1	Simulated 100 m	Planned	No	As quickly as possible without sacrificing accuracy (No hard constraint).	Individual
1998	Hagman	Silhouette (E & F-Type)	1	50 – 300 m	Unplanned	No	Prescribed exposure time (Constraint not defined)	Environmental
1998	Tharion & Obusek	Circular	1	Simulated 100 m	Planned	No	As quickly as possible (No hard constraint)	Task
2000	Anderson & Plecas	Silhouette	1	2-25 m	Planned	No	6 shots in 3 s 12 shots in 3 s 6 shots in 8 s 12 shots in 45 s	Individual
2001	Johnson et al.	Silhouettes.	Zeroing task: 1 Moving target task: 1-2	25 m 25-300 m	Unplanned	No	No Constraint	Individual
2001	Kemnitz et al.	Circular	1	Simulated 100 m	Planned	No	Not Defined	Task, Individual
2002	Charles & Copay	Silhouette	1	15 yd	Planned	No	No Constraint	Individual
2003	Evans et al.	Not Defined	1	Simulated 75 m	Unplanned	No	2 s	Task
2003	Gillingham et al.	Conventional pop-up targets (E-type)	Friend-foe task: 1 Vigilance task: 1	200 m	Unplanned	Yes	4 s	Individual
2003	Tharion et al.	Circular	1	Simulated 50 m	Planned	No	Shoot as quickly as possible without sacrificing accuracy (No hard constraint).	Individual
2004	Meyerhoff et al.	Human	Not Defined	Not Defined	Unspecified	Yes	Not Defined	Environmental
2005	Dias et al.	Circular	1	10 m	Planned	No	No Constraint	Individual
2006	Evelyn-Rose et al.	Not Defined	Not Defined	Not Defined	Unplanned	Yes	No Constraint	Task

2008	Oudejans	Low-pressure situations: Silhouette High-pressure situations: Human	1	5-8 m 5-8 m	Planned	No	Shoot before shot (No hard constraint)	Task, Individual
2009	Hatch et al.	Silhouette (E-type)	1	50-300 m	Unplanned	Yes	5s exposure per target	Individual
2009	Pojman et al.	20 in target (Not defined)	1	Simulated 200 yd	Planned	No	No Constraint	Individual
2010	Ortiz et al.	Computer-generated forces.	Not Defined	Not Defined	Unplanned	No	74-94 targets in 4-4.5 min	Task
2012	Frykman et al.	Silhouette	1	Simulated 150 m	Planned	No	7.5 s per shot	Task
2012	Jovanović et al.	Silhouette	1	15 m	Planned	No	No Constraint	Individual
2012	Ysebaert et al.	Not Defined	1	Simulated 200 ft	Unplanned	No	No constraint	Task
2013	Strandenes et al.	Not Defined	1	Nondominant hand: 6 m Dominant hand: 10 m 2 +1 task: 10m Precision tasks: 18-25 m	Planned	No	No Constraint	Individual
2014	Archer	Not Defined	Not Defined	200-500 yd	Not Defined	No	No Constraint	Environmental
2014	Hoffman et al.	Headshots	Not Defined	40 m	Planned	No	As quickly as possible (No hard constraint)	Individual
2014	Moore et al.	Silhouette	1-2	simulated 15-100 m	Unplanned	No	Ten targets in 30-49 s (No hard constraint)	Individual, Environmental
2014	Nibbeling et al.	Decision and shoot task: Human Shooting accuracy task: Mannequin or Human	1 1	5 m 5 m	Unplanned	Yes	As quickly as possible (No hard constraint)	Task, Individual
2014	Taverniers & De Boeck	Cardboard task: Silhouette Force-on-force: Humans	2	Not Defined	Planned	No	No time constraint	Task
2014	Thomasson et al.	Silhouette Simulated: Human Shoot/don't-shoot task: Picture (Depicting threatening and non-threatening targets)	1	1-25 yd	Unplanned	Yes	Run-and-shoot task: time constraint. Simulated task: If participants took too long identifying a target, blank ammunition would be fired by the instructor.	Task
2015	Clemente-Suarez & Robles-Pérez	Silhouette	1	Static task: 7 m Dynamic task: 2-6 m	Planned; Unplanned	No	No Constraint	Individual
2015	Hoffman et al.	Headshot	1	30 m	Planned	No	5 s for three shots	Individual
2015	Jaworski et al.	Silhouette	1	50 m	Planned	No	20 s for 10 shots	Task
2015	Lewinski et al.	Silhouette	1	3-15 ft 18-45 ft 60-75 ft	Planned	No	Shoot as quickly as possible (No hard constraint).	Individual
2016	Brown et al.	Silhouette (E-Type)	1	Live fire: 75 m Simulated: 75 m	Planned	No	No Constraint	Task, Environmental
2016	Landman et al.	Human	1	5 m	Unplanned	Yes	Shoot before shot (No hard constraint)	Individual
2016	Lawson et al.	Silhouette	1	Simulated 50-300 m	Unplanned	No	6 s per target	Individual
2016	McNamara et al.	Silhouette (E-type)	5	Simulated 75 m	Planned	No	Shoot as quickly as possible without sacrificing accuracy (No hard constraint).	Task

2016	Raisbeck et al.	Picture (Depicting male perpetrator holding a handgun)	2	6 m	Planned	No	13 s (firing two rounds, ejecting the magazine, reloading, firing another two rounds)	Task, Individual
2017	Brown & Mitchell	Not Defined	1	5 m	Planned	No	No Constraint	Task, Individual
2017	Head et al.	Silhouette (E-type)	1	25-100 m	Planned; Unplanned	Yes	0.6 s exposure and a 2.5 s inter-stimulus interval	Individual
2017	LaPorta et al.	Silhouette	3	50- 150 m	Planned	No	Two min for 12 shots.	Task
2017	Luken & Yancosek	Not defined	Standard qualification test: 1 Rapid fire test: 10	50-300 m 50-300 m	Unplanned	No	Rapid fire test: 10 targets in 40 s.	Task
2017	Morelli et al.	Not defined (40 x 50 cm target with a 2.5 x 2.5 cm square contrast box)	1	50 m	Planned	No	Self-paced task: no constraint Controlled-pair sequence: 2 s for two shots on two targets.	Task
2017	Nieuwenhuys et al.	Human	1	5 m	Planned	No	Shoot as quickly as possible without sacrificing accuracy (No hard constraint).	Task
2017	Tenan et al.	Not Defined (Olive Drab Green; white 2 x 2-in square in the centre)	1	100-150 m	Planned	No	8 s per shot	Task, Individual
2018	Andersen et al.	Human	Not Defined	Not Defined	Unplanned	Yes	Not Defined	Task
2018	Brown et al.	Silhouette	2	5 m	Planned	No	No Constraint	Task
2018	Gamble et al.	Human (Simulated	2	Not Defined	Unplanned	Yes	2 s	Task
2018	Liu et al.	High stress: Humans Low stress: Manikin	Not Defined	3.5 x 2.5 x 2.8 m room	Unplanned	Yes	As quickly as possible (No hard constraint)	Individual, Environmental
2018	Ojanen et al.	Not Defined	1	10 m	Planned	No	No constraint	Individual
2018	Spangler et al.	Human (Avatars)	2	Not defined	Unplanned	Yes	Behavioural task: 2 s	Task
2019	Gepner et al.	Headshot	1	30 m	Planned	No	No constraint	Individual
2019	Gil-Cosano et al.	Not defined	1	Simulated 300 m	Planned	No	No Constraint	Task
2019	Hamilton et al.	Marksmanship task: Bullseye target. Shoot/don't shoot: Picture (Depicting a Caucasian man)	1	10 yd Not Defined	Planned; Unplanned	Yes	No Constraint 1 s target exposure	Task
2019	Muirhead et al.	Static task: Silhouette Dynamic task: Silhouette Discrimination task: Silhouette	1 1 3	10 yd 1.5-10 yd 10 yd	Planned; Unplanned	Yes	No constraint As quickly as possible (No Hard Constraint) 4 s	Task, Individual
2019	Nestler et al.	Silhouette	1	5-10 m	Planned	No	No constraint	Task
2019	Oliver et al.	Not Defined	Not Defined	Zeroing: M9: 10 m; M4: 25 m Group size: M9: 10-30 m; M4: 100-200 m	Planned	No	No Constraint	Individual
2019	Rábago et al.	Silhouette (E-Type)	20	Not Defined	Unplanned	Yes	No Constraint	Individual
2019	Vandewal et al.	Circular	1	25 m	Planned	No	As quickly as possible (No hard constraint)	Environmental
2019	Vit et al.	Not Defined	1	10 m	Planned	No	As quickly as possible (No hard constraint)	Task
2019	Weinand & Rommel	Circular; rectangular	6	3-12 m	Planned	No	As quickly as possible (No hard constraint)	Task, Environmental

2020	Amini & Vaezousavi	Not defined	1	Not Defined	Planned	No	No Constraint	Task
2020	Bernardo et al.	Circular	1	2 m	Planned	No	No Constraint	Task, Environmental
2020	Brown & Mitchell	Circular	6	Simulated 75-200 m	Planned; Unplanned	Yes	No Constraint	Task
2020	Brown et al.	Circular	2	simulated 75-150 m	Planned	No	No Constraint	Individual
2020	Enders et al.	Not Defined (COM of a simulated target)	Task 1: 1 Task 2: 1-2	Task 1: Simulated 175-300 m Task 2: Simulated 35-300 m	Planned; Unplanned	No	Task 1: No Constraint Task2: 3-8 s	Task
2020	Hamilton et al.	Single target room: Silhouette Peripheral-target acquisition room: Silhouette Shoot/don't shoot decision: Picture (photo-realistic targets)	Single target acquisition room: 1 Peripheral-target acquisition room: 3 Shoot/don't shoot room: 3	Not specified (room clearing)	Planned; Unplanned	Yes	As quickly as possible (No hard constraint)	Task, Environmental
2020	Klymovych et al.	Not Defined	Not Defined	Not Defined	Not Defined	No	Not Defined	Individual
2020	Merchan & Clemente-Suárez	Not Defined	Not Defined	Not Defined	Not Defined	No	Not Defined	Task, Individual
2020	Nadler et al.	Not Defined	1	50 m	Planned	No	60s (100 m sprint, five shots kneeling and five shots prone)	Individual
2021	Brown et al.	Not Defined	1	Stage 1: 82 ft Stage 2: 49 ft Stage 3: 23 ft Stage 4: 16 ft Stage 5: 10 ft	Planned	No	Stage 1 & 3: No constraint Stage 2: 8 shots in 20 s Stage 3: No Constraint Stage 4: 3 shots in 5 s Stage 5: 8 shots in 15 s	Individual
2021	Sia et al.	Alternate Qualification target	10	25m (scaled to represent 50 - 300 m)	Planned	No	No time constraint	Individual
2021	Taylor	Human (Simulated)	1	Not Defined	Unplanned	Yes	Respond faster than the threat (No Hard constraint)	Task
2021	Tornero-Aguilera et al.	Not Defined	1	7 m	Planned	No	Not Defined	Individual
2021	Vágner et al.	Circular	1	Static: 20 m Dynamic: 15-5 m	Planned	No	5 shots in a 10 s No constraint	Task
2022	Buckley et al.	Projected numbers (1 to 9 in red, yellow, green and blue)	6	4.88 m	Unplanned	Yes	As quickly as possible (No hard constraint)	Task
2022	Buskerud et al.	Circular target	1	100 m	Planned	No	Shoot as quickly as possible without sacrificing accuracy (No hard constraint).	Individual
2022	Cook et al.	Human (Simulated)	1-2	15 ft	Unplanned	Yes	Shoot before shot (No Hard constraint)	Environmental
2022	Di Stasi et al.	Coloured 2D geometric figures	Low complexity: 2-4 High complexity: 5-7	7.5-8 m	Unplanned	Yes	2 s	Task, Environmental
2022	Jamro et al.	Not Defined	1	Rifle shooting task: 100 m Pistol shooting task: 15 m	Planned	No	No Constraint	Individual

2022	Jamro et al.	Not Defined	1	Rifle shooting Task: 100 m Pistol shooting Task: 15 m Machine pistol shooting task: 75 m Rifle shooting task with a gas mask: 100 m	Planned	No	No Constraint	Individual
2022	Karaduman et al.	Circular	1	1 0m	Planned	No	No Constraint	Individual
2022	Ku et al.	Baseline shooting task: Silhouette (E-type) One-on-One task: Human	Baseline shooting task: 1 One-on-One task: 1	Baseline shooting task: 50 – 250 m One-on-One task: 75 m	Unplanned	No	Baseline shooting task: 3 s	Task
2022	Löfgren & Hansson	Silhouette (circular target inside)	1	Subtest 1: 7 m Subtest 2: 7 m Subtest 3: 20 m	Planned	No	Subtest 1: 5 rounds in 2 s exposure Subtest 2: 5 rounds in 3 s exposure Subtest 3: 5 rounds in 90 s exposure	Task, Environmental
2022	Zotov & Kramkowski	Human (Animated) Silhouette (E-Type, Animated)	1	Simulated 100 – 250 m	Unplanned	No	As quickly and as accurately as possible (No hard constraint)	Task
2022	Zurek et al.	Not Defined	Not Defined	Not Defined	Not Defined	No	Not Defined	Individual
2023	Biggs et al. (Experiment 2)	Silhouette	7	<30 ft	Planned; Unplanned	Yes	As quickly as possible (No hard constraint)	Individual
2023	Coleman et al.	Not Defined	1	50 m	Planned	No	No Constraint	None
2023	Földes et al.	Olympic-type bullseye targets (Circle)	1	Simulated: 25 m	Unplanned	No	10 s for 8 shots 10 s for 7 shots 10 s for 5 shots	Task; Environmental
2023	Ibrahim et al.	Circle (10-ring)	1	10 m	Planned	No	No constraint	Task; Individual
2023	Jensen et al.	Humans, photorealistic targets	8	Shoot house (85 m^2)	Unplanned	Yes	As quickly as possible	Task
2023	Kostoulas et al.	Circular	1	Simulated 100 m	Planned	No	As quickly as possible (No hard constraint)	Task, Individual
2023	Maleček et al.	Circular (20 cm)	1	Simulated 10 m	Planned	No	1 min for 10 shots	Individual
2023	Nykänen et al.	Not Defined	1	10 m	Planned	No	No Constraint	Individual
2023	O'Donovan et al.	Silhouette	4	5-100 m	Planned	No	As quickly as possible whilst maintaining accuracy	Individual
2023	Ojanen et al.	Not Defined	1	Not Defined	Planned	No	Not Defined	Individual
2023	Pedrosa et al.	Silhouette	7	7-15 m	Planned	Yes	As quickly as possible whilst maintaining accuracy	Individual
2023	Shi et al.	Silhouette (chest ring target paper chart)	1	Not Defined	Planned	No	No Constraint	Environmental
2023	Talarico et al.	Silhouette	1	10-15 m	Planned	No	No Constraint	Task
2023 (In Press)	Haddadiniya et al.	Not Defined	1	100 m	Planned	No	No Constraint	Individual

4.3.4 What types of firing actions and targets are employed in the combat shooting literature, and do studies incorporate the representative constraints of body-worn equipment?

The included articles used three different modes of firing: 61 studies (58.1%) used live firing in at least one of the shooting tasks, 38 (36.2%) used simulated firing procedures, and 9 articles (8.6%) included dry firing.

Target type was categorised into two: representative targets and non-representative targets (*Table 2*). For the purposes of this study of combat shooting, representative targets are those that represented human form, including: silhouettes, humans (including simulated) and images (photo-realistic depictions of humans). Non-representative targets included the following: headshot, circular shapes, and others (aiming point, 20", Bullseye, rectangular, alternate qualification, numbers, geometric-shaped). Overall, 50.9% of study tasks included representative targets, 24.1% used unrepresentative targets, with task target type being undeterminable in 25.0% of studies.

Body-worn equipment was categorised into three categories: 'representative body-worn equipment', 'non-representative body-worn equipment' and 'not defined'. For this review, representative body-worn equipment was defined as that used in combat, in occupation, for safety reasons (e.g., tactical vest, belt, boots, helmet, backpack, uniform, safety equipment (armour, hearing protection, gloves), or to simulate constraints representative of body-worn equipment). Non-representative body-worn equipment was anything not defined in the representative category. If the type of body-worn equipment used was not discernible, a study was categorised as not defined. A large proportion of studies

(46.7%) used representative body-worn equipment. No studies used non-representative equipment, with 53.4% not defining what body-worn equipment was used.

5. Discussion

5.1 Main Discussion

To our knowledge, this is the first scoping review using ecological dynamics as a conceptual framework to evaluate properties of representative design in combat shooting analysis. The outcomes of this review could contribute to improving task design in training and assessment to better prepare tactical populations for the often extreme, highly demanding, and ambiguous environments where they typically operate.

It must be stated, although practitioners are seeking a perfectly representative environment, ecological validity is not possible.[18,30] Some technologies, like motion capture, are often bound to a laboratory environment, meaning live firing is not possible for health and safety reasons, or eye trackers are required for gaze evaluation, which means a target cannot fire simulated ammunition back at the shooter; both these examples are compromises needed to maintain the safety of participants and staff. This discussion will highlight critical limitations in the current combat shooting research so that future research can focus on innovative methodological designs, incorporating more representative constraints or designing new technologies that may support progress in this research area.

5.1.1 What individual, task, and environmental constraints have been used during combat shooting performance assessments?

Manipulation or observation of task and individual constraints feature most in the included article, with environmental constraints only considered in 13.3% of studies. Combat zones are varied, including physical environments and the social world in which agents operate (e.g., history, cultural norms, traditions, beliefs), which can shape behaviours and vary the dynamics of different contexts.[15] Only one study in this review investigated social constraints on shooting task performance with stereotype threat (e.g., women are less experienced than men at marksmanship), finding a reduction in performance when the stereotype threat is present.[36] The other thirteen studies investigated varying environmental constraints of a contextual nature, such as differences between performance in simulated and live firing ranges,[37–39] and effects of noise within the environment,[40–43] altitude,[44] dazzling light within the environment,[45,46] day and night conditions,[43,47,48] and realistic combat shooting environments (e.g., field, pulled over car, conference room, night call-out, living room, and a truck's trailer).[49] More work is required to understand how manipulating specific environmental constraints affects tactical populations when combat shooting, as this is the most underrepresented analysis within the body of research. In particular, research has overlooked that all combat shooting actions emerge within socio-cultural-historical environments and climate (e.g., stereotype threats, cultural norms, rules of engagement)[15] that can subtly influence behaviours and coordination dynamics and, therefore, lethality, presenting an opportunity to better understand the environmental constraints that influence combat shooting.

When evaluating effects of constraints on performance, most studies in this review focused on performance outcomes like score, accuracy, or precision. Most studies did not look at the rifle end-point control nor the effects of constraints such as sighting equipment, uncertainty, or physical fitness on the biomechanics of the shooter's actions or perceptual search strategies. As constraints from an individual, task, and environment can all affect biomechanics of performance, perception,[50] and rifle endpoint movement control, there is a need to evaluate how tactical populations adaptively coordinate new strategic behaviours to maintain lethality.

5.1.2 What static-dynamic, agent-target task constraints are employed when assessing combat shooting performance in combat shooting methodologies?

Over time, studies have started to incorporate dynamic methodologies to a greater extent. However, even in the 2020s, 51.3% of studies only tended to use static tasks when assessing shooting performance (See supplementary material 2). The lack of a dynamic component in the task context could reduce action fidelity. High action fidelity potentially facilitates a better transfer of behaviours from training and testing to the combat performance environment.[18] Skills and strategies used in static tasks may not transfer directly to performance in dynamic combat environments, questioning the validity of these methodological designs.[18]

Henriksen and Kruke[51] evaluated law enforcement training in Norway and New Zealand, finding limited use of dynamic targets. This trend is apparently not specific to these countries; in this review, only 20.0% of studies included a dynamic target. More studies adopted a dynamic agent methodology (28.6%) instead of using a dynamic target context, likely due to the extra costs and equipment associated with dynamic target protocols. With 56.2% of research still being solely static in design, the validity, and conclusions of much of the combat shooting research, regarding performance in a combat setting, may be difficult to interpret.[18]

5.1.3 Have studies investigated the ambiguity of target selection, and if so, how have they created ambiguous and uncertain environments for participants and constrained their time to perceive and act?

With the ambiguity and uncertainty inherent in a modern combative military environment, such as asymmetric combat scenarios, which have different physiological demands compared with symmetric combat, it is critical to create ambiguous, uncertain environments in training and assessments whilst limiting the time available to perceive information and act.[1,26] Protocols included in this review were mostly planned (68.6%; low emergence of information). Planned protocols may reduce action fidelity due to a lack of congruence between specific dynamics emerging in training and assessment contexts and those typically required in a combat setting. For example, in the case where tactical populations already know the locations of enemy targets (information not ordinarily present in combat zones), there is a reduced requirement for visual search behaviours for relevant information and selection of affordances available in a combat landscape and use of adaptive variability is also limited. These designs limit the extent to which individuals self-organise to satisfy constraints of uncertain environments because the need to search for information is not included.[13,27,52] One study in this review investigated differences between planned and unplanned shooting tasks (e.g., targets were obscured and visible to participants before starting the shooting performance test), finding that the obscured task took longer to complete, and that more 'friendly targets' were shot in the visible condition.[53] Analysis of performance between planned and unplanned tasks clearly indicate that they have different task constraints. As unplanned tasks are more likely found in modern combative military environments, including more of these activities in training may better prepare shooters for navigating combat environments.[1]

Task ambiguity was also investigated by examining the number of targets presented in a single instance to participants within a task design (affordance landscape). For example, a study could have presented ten targets throughout a task, one at a time (one source of information at a time; low ambiguity), or they could have presented ten targets concurrently (ten sources of information at a time; high ambiguity; greater perception, cognition and action loading). Across all articles in this review, only 23.8% of studies included multi-target engagements simultaneously. As combat is not always dyadic (one-on-one), understanding how multi-target engagement scenarios, with increased task ambiguity, shape and modify emergent movement dynamics, would be beneficial. There is clearly a rationale for including multi-target engagements more frequently in combat shooting research and training, improving the representative design of methodologies by including the ambiguities of combat environments.

Only 23.8% of studies within this review included a task involving friend-or-foe discrimination (information uncertainty). As Clemente-Suárez & and Robles-Pérez[1] mention in their introduction, modern combat zones have civilians present, and law enforcement is frequently faced with 'shoot, do not shoot' decisions.[54] With a low number of studies including target discrimination within their task design, more research is required to understand effects of various task constraints, tested in the other 76.2% of research, which did not include a 'friend-or-foe' task, on the correct identification of targets that afford engagement. The extra layer of ambiguity in friend-or-foe tasks could significantly change emergent behaviours and how constraints interact to shape visual search strategies.[27]

The mitigation of task ambiguity within the combat shooting literature could be due to the lack of suitable facilities. Complex shoot houses and ranges are expensive and usually reserved for higher skill-level tactical populations. They also require more safety considerations and staff to run, making them inaccessible to training participants of lower skill levels, where static ranges are more common and cheaper to operate. However, variations in temporal constraints can still be included, even in static environments. Moving forward, newly built training centres should aim to implement facilities where a more comprehensive array of representative constraints can be integrated into training.

Temporal constraints were investigated for all studies, as the time afforded by properties of a performance environment impinging on how an agent perceives affordances in the landscape.[26] Most studies did not place ‘hard’ constraints on participants, which have consequences for not acting (e.g., shooting before a foe target shoots and critically hits the participant or a target is only presented for a limited time). ’Softer’ constraints included instructing participants to shoot as quickly as possible without sacrificing accuracy (speed-accuracy trade-off). A hard constraint cannot be exceeded (the task fails if a shot is not taken within a time limit); this is more representative of combat environments because if an enemy is spotted, the agent will have limited time to perceive and respond to the threat.[26] Being afforded limited time to act when engaged in combat shooting means future research could employ a methodological approach that examines the effects of constraints on both time-to-act and the number of successful hits, not just one variable, as both have implications for survivability.

5.1.4 What types of firing actions and targets are employed in the combat shooting literature, and do studies incorporate the representative constraints of body-worn equipment?

Using targets with likenesses to those seen in combat environments, such as human targets, silhouettes, or images, could be very important to support action fidelity and information functionality – 50.9% of studies used these types of targets. If targets are used which are not seen in combat military environments, the link between perception and action may not properly stabilise as tactical populations may not attune to specifying perceptual information sources. This limitation in training could lead to false positive target identifications, increase civilian casualties, and endanger the life of the combatant. As 24.1% of studies used targets not seen in combat zones, it is vital to understand whether the outcomes and conclusions of those studies would be valid in more representative performance environments or whether target informational properties do not affect performance behaviours, coordination, and action fidelity. The reporting of targets used in research needs to improve as it could not be determined what targets were used in 25.0% of studies; this is not trivial since this information could have significantly influenced the data in this review and the conclusions drawn.

The current review found that 58.1% of articles used 'live fire' scenarios, 36.2% had simulated, and 8.6% had dry firing. Live firing is advantageous as it has the most information functionality due to the presence of recoil, which is not experienced in dry firing methodologies, as live ammunition is not fired, thus not applying a reaction force through the gun. Recoil needs to be controlled to remain accurate and ready for subsequent shots.[55] Therefore, dry firing has reduced information functionality compared to live firing when there is a need to control recoil. If recoil is not present in training, a shooter could fail to gain relevant experience in controlling it. This could result in reduced action fidelity as the developed coordination dynamics do not satisfy the task constraints imposed by live firing when acting in a goal-directed way. Conversely, dry firing has reduced safety concerns and can be applied to more dynamic training designs as a rifle does not need pointing in one direction of fire (down range), making it a viable tool for learning to shoot more dynamically and not just in static linear positions. Similarly, simulated ammunition types (simunition FX weapons, airsoft, and paintballs), which fire non-lethal projectiles, can mitigate some safety considerations of live firing[31] allowing the implementation of representative constraints which increase task ambiguity and dynamic interactions within combat shooting training. Due to the health and safety risks of firing live ammunition, it is not possible to have human targets within the environment; losing information functionality when training tactical populations to identify 'friend-or-foe' simulated ammunition, which has low injury risks, could aid in the preservation of representative target information in the environment. This also requires some need to control recoil, having the greater level of information functionality for training designs.[30]

When investigating use of representative body-worn equipment in combat shooting assessments, 53.4% of studies did not define the equipment worn. Research has already investigated effects of varying equipment-related task constraints on shooting performance, from load carriage, body armour, and military equipment, finding effects on shooting performance.[56–58] Brown and Mitchell[59] also demonstrated how equipment can have a greater effect on dynamic shooting performance than static, highlighting how various constraints interact to modify performance. Effects of body-worn equipment are not incidental and could change task outcomes, possibly making it difficult for practitioners to interpret research findings that do not disclose what body-worn equipment was worn. As organisations and shooting ranges have safety regulations, it is likely that participants were wearing representative equipment in the studies that did not disclose what a participant was wearing. This is feasible because, in no study of this review did participants wear non-representative equipment. Rather, it was not possible to discern and confirm what equipment they did use (and the implications for performance).

5.2 Limitations

The design of this scoping review had at least two reviewers at every stage, apart from the data extraction stage, which only had one reviewer. This may have led to the reviewer's subjective biases influencing data extraction. However, key terms in this paper (e.g., planned or unplanned, static or dynamic) were clearly defined before data extraction in order to mitigate this risk, and a second team member (CP) verified the selection of sources. If study designs were unclear and did not fit the definitions, they were placed into an 'undefined' category.

Some studies had variables and constraints that were impossible to discern from their methods sections. This feature may have influenced the analysis conducted within this review. For example, all studies will have a static or dynamic agent or target interaction (i.e., the target or the participant is still or in motion when shooting). However, some methods were not detailed enough to interpret which static-dynamic interaction was used. Furthermore, not all studies provided details of the targets or body-worn equipment used. A standard reporting protocol for combat shooting studies in future is required to explain the methods fully, for example, reporting the static-dynamic nature, targets used, firing type, body-worn equipment, the task ambiguity (or lack thereof), time available to perceive and act, and the constraints imposed.

For this review, silhouette, human (including simulated), and image targets were classified as representative target types. What constitutes a representative target and the effects of varied target types on combat shooting performance need further investigation. Jensen et al.[60] observed performance differences between using actual enemy combatants firing nonlethal training ammunition as targets and photo-realistic targets, demonstrating the sensitivity of a performer's attunement to information for coupling perception and action and how the use of different targets can affect tactical populations' physiology (individual constraints). Liu[61] witnessed a similar finding, showing that using real human targets compared to 'dummies' in a SWAT hostage rescue task reduced performance and increased heart rate and self-reported stress level. This finding suggests that training with human targets could aid in reducing anxiety. A new line of enquiry is needed to understand how other target types may affect performance and what targets most represent those in military combat environments.

Another limitation of this scoping review is the lack of consensus on what is universally deemed and defined as *combat shooting*. In this review, combat shooting, law enforcement, and marksmanship have all been included if they required survivability and investigated a relevant population.[6] A common accepted definition is required to unite a coherent field of research around the same topic to help reduce the irrelevant citing of Olympic sports shooting literature (or other shooting contexts not associated with combat), which has low representativeness to the combat context. Other sporting contexts may be helpful to investigate, like that seen in the International Practical Shooting Confederation (IPSC), if the methodologies have sampled a range of constraints highlighted in this paper. As the ecological dynamics framework has been successfully employed in this scoping review to understand the representative design of combat shooting research, it could further aid in defining the actions of combat shooting and their nuances in combative performance environments.

The current scoping review's data extraction and discussion are focused on the performance of individuals. Team task designs have not been evaluated. As combat operators tend to work in teams, future research must also implement tasks to evaluate combat team performance, investigate the dynamics between members, and determine how to implement this into representative research and practice design.[62] Future research could also investigate the effects of training in team environments compared to individually and how these experiences transfer to team combat assessments.

6. Conclusion

This scoping review evaluated the representative design of combat shooting research methodologies framed by an ecological dynamics framework, because of the emphasis on understanding the person-environment relationship in training and performance. The review found that task designs used in current research generally do not represent combat scenarios. This limitation was exemplified by the frequent use of static methodologies, single target engagements, pre-planned protocols, and infrequent use of temporal constraints and 'friend-or-foe' discrimination tasks. Future research should implement unplanned, dynamic, multi-target engagements that are temporally constrained and require the 'friend-or-foe' discrimination into their task designs for greater action fidelity and information functionality when seeking to improve tactical populations combat shooting expertise, coordination skills and survivability.

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