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Dueler's dilemma:

A one-person computer gaming platform for decision-making

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Defence R&D Canada
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Abstract

'Dueler's Dilemma' is one-person computer-based interactive game whereby the player, hereafter referred to as the subject, engages an unseen opponent in a non zero-sum silent shooting duel. Shots fired on a time scale from 0 to 100 by either the subject or opponent have a linearly increasing chance of hitting their target from 0 to 100%, respectively. However, the probability that either target is hit depends on the combination of shooting times that the subject and opponent chooses (e.g., if the opponent shoots first, the subject's only chance of hitting the opponent depends on being missed by the opponent's shot). The shooting times chosen by the opponent generally vary and are concealed from the subject. Further, the probability of being hit changes with each engagement, even if the subject chooses to shoot at the same time as in a previous engagement. However, patterns will emerge with a sufficient number of engagements and the subject's objective is to converge to an optimal shooting time. After each engagement, the subject is presented with a display of the outcome, either in discrete or distributional format. Dueler's Dilemma is presented as a versatile gamming platform suitable for researching life-critical decision making under time constraints. Its simplistic rule structure complemented by the considerable latitude in shaping the opponent's shooting strategy makes it an attractive investigative tool for exploring behavioural responses regarding force application and force protection, as demonstrated through various scenarios.

Résumé

« Dueler's Dilemma » est un jeu informatique interactif solo dans lequel le joueur, ci-après appelé le sujet, s'engage dans un duel de tir silencieux non nul avec un adversaire qu'il ne voit pas. Les tirs déclenchés sur une échelle de temps allant de 0 à 1 par le sujet ou par l'adversaire ont une chance linéairement croissante d'atteindre leur cible de 0 à 100 % respectivement. La probabilité que chacune des cibles soit atteinte dépend toutefois de la combinaison de temps de tir que choisissent le sujet et son adversaire (p. ex. si l'adversaire tire en premier, la seule chance qu'a le sujet de l'atteindre dépend de ce que l'adversaire ait manqué sa cible). Les temps de tir choisis par l'adversaire ne sont ni prévisibles ni connus du sujet. De plus, la probabilité d'être touché change à chaque engagement, même si le sujet choisit le même temps de tir qu'au cours d'un engagement précédent. Des schémas se dégageront toutefois après un nombre suffisant d'engagements, et l'objectif du sujet est d'en arriver à un temps de tir optimal. Un affichage du résultat est présenté au sujet après chaque engagement, en format discret ou en format de distribution. Dueler's Dilemma se présente comme une plate-forme de jeu polyvalente permettant d'étudier la prise de décision critique sous pression. Sa structure de règle simpliste et la latitude considérable laissée au sujet pour déceler la stratégie de tir de l'adversaire en font un instrument de recherche intéressant, comme en témoignent divers scénarios.

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Executive summary

Dueler's dilemma: A one-person computer gaming platform for decision making

Peter Tikuisis; Keefe, Allan A.; DRDC Toronto TM 2007-091; Defence R&D Canada – Toronto; November 2007.

‘Dueler’s Dilemma’ is one-person computer-based interactive game that engages the player against an unseen opponent in a non zero-sum silent shooting duel. Shots fired on a time scale from 0 to 100 by either the subject or opponent have a linearly increasing chance of hitting their target from 0 to 100%, respectively. However, the probability that either target is hit depends on the combination of shooting times chosen by the subject and the opponent (e.g., if the opponent shoots first, the subject’s only chance of hitting the opponent depends on being missed by the opponent’s shot). The shooting times chosen by the opponent generally vary and are concealed from the subject, and the probability of being hit changes with each engagement, even if the subject chooses to shoot at the same time as in a previous engagement. The challenge for the subject arises in the tension between delaying engagement long enough to allow a high probability of successfully hitting the opponent, but not waiting too long to avoid being hit by an earlier shot taken by the opponent.

The purpose of the game is to introduce a test platform suitable for conducting research on life-critical decision making under time pressure that may be particularly relevant to hostile situations. Dueler’s Dilemma is sufficiently complex with adjustable levels of challenge, yet simple to administer and uncontaminated by extraneous features indigenous to most commercially-available single-player games of conflict. The subject’s task is to converge to an optimal shooting time based on maximizing either their survival or hit rate. After each engagement, the subject is presented with a display of the outcome, either in discrete or distributional format. After a sufficient number of engagements, a pattern should become apparent that reveals the opponent’s shooting strategy.

It is envisioned that studies using Dueler’s Dilemma will probe the effects of various stressors, whether physiological or psychological, of various emotions, of command and training, etc. on the intense decision making inherent in the task. Potentially important additional information on life-critical decision making may also be found by combining the test with neurophysiological measurements such as fMRI, for which Dueler’s Dilemma is well suited. In essence, the game facilitates the analysis of behaviours related to strategies involving force protection and force application.

Sommaire

Dueler's dilemma: A one-person computer gaming platform for decision making

Peter Tikuisis; Keefe, Allan A.; DRDC Toronto TM 2007-091; R & D pour la défense Canada – Toronto; Novembre 2007.

« Dueler’s Dilemma » est un jeu informatique interactif solo dans lequel le joueur, ci-après appelé le sujet, s’engage dans un duel de tir silencieux non nul avec un adversaire qu’il ne voit pas. Les tirs déclenchés sur une échelle de temps allant de 0 à 1 par le sujet ou par l’adversaire ont une chance linéairement croissante d’atteindre leur cible de 0 à 100 % respectivement. La probabilité que chacune des cibles soit atteinte dépend toutefois de la combinaison de temps de tir que choisissent le sujet et son adversaire (p. ex. si l’adversaire tire en premier, la seule chance qu’a le sujet de l’atteindre dépend de ce que l’adversaire ait manqué sa cible). Les temps de tir choisis par l’adversaire ne sont ni prévisibles ni connus du sujet et la probabilité d’être touché change à chaque engagement, même si le sujet choisit le même temps de tir qu’au cours d’un engagement précédent. Le dilemme du sujet consiste à choisir un temps de tir assez long pour avoir une probabilité élevée de toucher la cible, mais pas assez long pour qu’un tir de son adversaire ne l’atteigne d’abord.

Ce jeu a pour but de présenter une plate-forme permettant d’étudier la prise de décision cruciale sous pression et convient particulièrement à des situations hostiles. Dueler’s Dilemma est assez complexe et offre des niveaux de difficulté réglables, mais il est simple à utiliser et il ne s’encombre pas des caractéristiques superflues que l’on retrouve dans la plupart des jeux solo commerciaux de conflit. Le sujet doit découvrir un temps de tir optimal en maximisant soit son taux de survie, soit son taux de destruction. Un affichage du résultat lui est présenté après chaque engagement, en format discret ou en format de distribution. Un schéma révélant la stratégie de tir de l’adversaire devrait se dégager après un nombre suffisant d’engagements.

On prévoit que des études faisant appel à ce jeu exploreront les effets de divers facteurs de stress physiologiques ou psychologiques, de diverses émotions, du commandement et de l’instruction, etc. sur la prise de décision intense qui est à l’origine du test. On peut tirer de ce test d’autres renseignements importants sur la prise de décision cruciale en le combinant avec des mesures neurophysiologiques comme l’IRMF, à laquelle Dueler’s Dilemma convient bien. Le jeu facilite essentiellement l’analyse de comportements liés à des stratégies faisant appel à la fois à l’emploi et à la protection de la force.

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1 Introduction

Studies involving decision making usually involve tasks that closely resemble the subject's normal course of activity or have a high likelihood of occurrence. Life and death decisions under time pressure, on the other hand, are rare but particularly relevant to military situations. Understanding an opponent's decision making process during the commission of violent action might help influence, pre-empt, or prevent such action from occurring. This was the motivation for the development of a task to explore rapid life-critical decision making in an adversarial context. Perpetrators of violent actions that disregard the safety of their own life and indeed who might welcome death (e.g., suicide bombers) fall outside the scope of this development. Our interest is in the development of a task where death is a potential, but unwelcome consequence of one's decision.

Ideally, the task should be portable and simple to administer, reproducible but not easily predictable, and amenable to other measurements (e.g., neurophysiological) being taken concurrently to augment research findings. Most commercially-available single-player games of conflict are designed for entertainment or training and simulation. Use of these games for experimental purposes is compromised by multiple strategic options and extraneous events/diversions. Following is a description of a one-on-one adversarial confrontational game with adjustable levels of difficulty that is sufficiently complex to challenge a player, yet simple to administer and uncontaminated by extraneous features. This game has relevance to the tension between force protection and force application, and can potentially contribute to the understanding of how people make judgements to resolve the two.

2 Task description

'Dueler's Dilemma' is a one-person nonzero-sum silent duel task whereby the subject must decide when to engage their opponent that is afforded the same accuracy function of hitting the subject, which is time-dependent. It differs from the classic version of a duel in that neither party can see or hear when their opponent fires a shot, nor see if their shot hit their opponent. This current variant of the duel is well described by Presman and Sonin (2006). The accuracy function of hitting a target is a simple linear relationship to when a shot is fired, based on a time scale from 0 to 100 (e.g., 0, 10, 20% at scaled times of 0, 10, 20, etc.). However, because neither the subject nor the opponent is aware of when the other chooses to shoot, the challenge for the subject arises in the tension between delaying engagement long enough to allow a high probability of successfully hitting the opponent, but not waiting too long to avoid being hit by an earlier shot taken by the opponent. Further, the shooting preference of the opponent can be 'shaped' to achieve a desired behaviour or strategy depending on the task requirement. The outcome of each engagement is displayed to the subject either in a discrete or distributional format, as described later on.

In the lexicon of game theory (Fudenberg and Tirole 1991; Myerson 1991), Dueler's Dilemma is well-defined by the strategic options available to both players and its consequences. However, the strategic form is complicated by the time dimensionality of hit probabilities, which will be fully described under the discrete display format. Given that the subject can benefit from changing his or her strategy irrespective of the opponent's strategy (which is programmed), the corresponding payoffs do not constitute a Nash equilibrium (Pressman and Sonin 2006).

3 Hit probabilities

An example engagement is provided to illustrate the possible outcomes. The convention adopted herein is to display the shooting time on a scale from 0 to 100 for experimental purposes, but to express it as a fraction (from 0 to 1) in the theoretical dvelopment for a one-to-one correspondence with the hit probability. Suppose the opponent engages the subject at $T_o = 0.75$ and that the subject chooses to engage the opponent at $T_s = 0.60$. The first possibility is that the opponent is hit with a 60% probability since the subject shoots first at a time of 0.60, which is associated with a hit accuracy of 60%. The next possibility is that the subject is hit, but only if the opponent survived the initial engagement, which has a probability of 40% (i.e., the complement of being hit at 60%). Hence, the probability that the opponent hits the subject is 40% times the hit accuracy of 75% (based on the opponent's shot time of 0.75), which equals 30%. The odds ratio (OR) of hitting the target over being hit therefore favours the subject by a factor of 2 (i.e., OR = 60/30) even though, in this example, the subject engaged sooner with a nominally lower hit accuracy.

The above can be formalized, as follows:

$$\text{Pr (subject being hit)} = \begin{cases} \mathrm{T_o} & \textit{if } \mathrm{T_o} < \mathrm{T_s} \\ (1-\mathrm{T_s})\cdot \mathrm{T_o} & \textit{if } \mathrm{T_o} \geq \mathrm{T_s} \end{cases} \tag{1}$$

and

$$\text{Pr (opponent being hit)} = \begin{cases} (1-\mathrm{T_o})\cdot \mathrm{T_s} & \textit{if } \mathrm{T_o} < \mathrm{T_s} \\ \mathrm{T_s} & \textit{if } \mathrm{T_o} \geq \mathrm{T}_s \end{cases} \tag{2}$$

where Pr is probability, and T_o and T_s are the engagement times of the opponent and subject, respectively. The ratio of the probabilities of the subject hitting the opponent over being hit is denoted as the 'kill' odds ratio, or OR (kill), given by:

$$\text{OR (kill)} = \begin{cases} (1-\mathrm{T}_o)\cdot \mathrm{T_s}/\mathrm{T_o} & \textit{if } \mathrm{T_o} < \mathrm{T_s} \\ \mathrm{T_s}/(1-\mathrm{T_s})/\mathrm{T_o} & \textit{if } \mathrm{T_o} \geq \mathrm{T_s} \end{cases} \tag{3}$$

and similarly the ratio of the probabilities of the subject not being hit over the opponent not being hit is denoted as the 'survival' odds ratio, or OR (survival), given by:

$$\text{OR (survival)} = \begin{cases} (1-\mathrm{T_o})/[1-(1-\mathrm{T_o})\cdot \mathrm{T_s}] & \textit{if } \mathrm{T_o} < \mathrm{T_s} \\ [1-(1-\mathrm{T_s})]\cdot \mathrm{T_o}/(1-\mathrm{T_s}) & \textit{if } \mathrm{T_o} \geq \mathrm{T_s} \end{cases} \quad (4)$$

The engagement time of the opponent, T_o, need not be fixed. Indeed, it can be shaped an infinite number of ways ranging from well-defined functions to complete randomization in order to achieve the desired behaviour/strategy. Several possibilities are detailed below beginning with the least complex case of a fixed engagement time.

3.1 Specific opponent engagement time

If the opponent's engagement time is fixed, then the outcomes can be calculated directly using Eqs. 1 through 4. Figure 1 illustrates the example where the opponent always engages the subject at $T_o = 0.75$, thereby fixing their hit accuracy at 75% (if given the opportunity to shoot). For example, if the subject chooses to shoot at $T_s = 0.2$, then the opponent has a 80% chance of not being hit and thus the subject is left with a 60% (80% x 75%) chance of being hit. But, if the subject chooses to shoot at $T_s = 0.8$, then the subject has a 25% chance of not being hit and the opponent is left with a 20% (25% x 80%) chance of being hit. In both of these examples, the subject has a lower probability of survival than the opponent. The region where the subject has a higher probability of hitting the opponent than being hit is denoted as the 'zone of advantage'. In this case, the zone of advantage is confined to engagement times from $0.42 < T_s < 0.75$ where the kill and survival odds ratios are greater than 1. Note that these odds ratios decrease sharply as T_s transitions from less than 0.75 to beyond 0.75 [OR(kill) transitions from 4 to 0.25, and OR(survival) transitions from 3.25 to 0.31], essentially reversing the subject's advantage since the opponent shoots first.

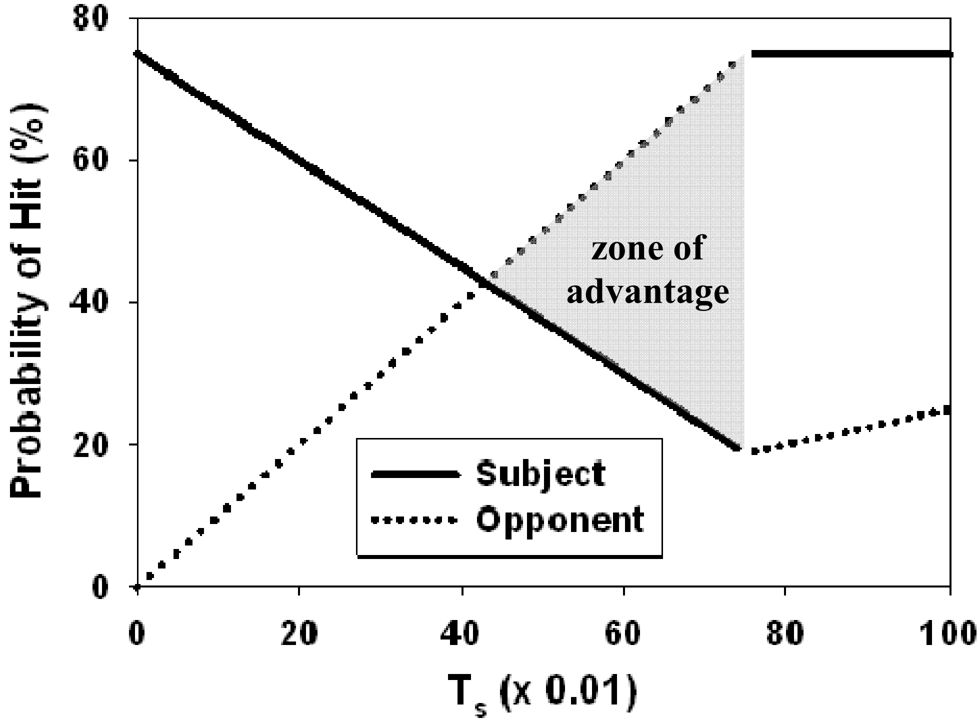

Figure 1. . Probabilities of being hit as a function of the subject's shooting time (T_s) when the opponent chooses to shoot at 0.75. The zone of advantage (for the subject) lies in the shaded range 0.42 < T_s < 0.75.

3.2 Completely randomized opponent engagement time

In this case, the opponent chooses to shoot at any time between 0 and 1 with each engagement, irrespective of previous encounters. The mean probability of the subject being hit is therefore determined through consideration of all possible opponent engagement times distributed uniformly, as follows:

$$\begin{aligned}\bar{\Pr}\text{ (subject being hit)} &= \int_0^{T_s} T_o \cdot dT_o \quad + \quad \int_{T_s}^{1} (1 - T_s) \cdot T_o \cdot dT_o \\ &= \frac{T_s^{\,2}}{2} \quad + \quad (1 - T_s) \cdot \left(\frac{1}{2} - \frac{T_s^{\,2}}{2} \right) \\ &= \frac{1}{2} \cdot \left(1 - T_s + T_s^{\,3} \right)\end{aligned} \tag{5}$$

and similarly the mean probability of the subject hitting the opponent is given by:

$$\bar{\Pr}\ (\text{opponent being hit}) = \int_0^{T_s} (1 - T_o) \cdot T_s \cdot dT_o \quad + \quad \int_{T_s}^{1} T_s \cdot dT_o$$

$$= T_s \cdot \left(T_s - \frac{T_s^{\,2}}{2} \right) \quad + \quad T_s \cdot (1 - T_s) \qquad (6)$$

$$= T_s - \frac{T_s^{\,3}}{2}$$

Figure 2 illustrates these probabilities as a function of the subject's shooting time. The zone of advantage (i.e., where the probability of the subject being hit is higher than the opponent being hit) begins at $T_s = 0.37$ and continues thereafter. Optimal shooting times (for the subject) can be defined either by minimizing the probability of the subject being hit (30.8% at $T_s = 0.58$), maximizing the probability of hitting the opponent (54.4% at $T_s = 0.82$), or maximizing the separation of hit probabilities (Δ of 20.7% at $T_s = 0.71$). These values and their corresponding odds ratios are summarized in Table 1. Note that the odds ratios are highest at the maximum separation of the hit probabilities.

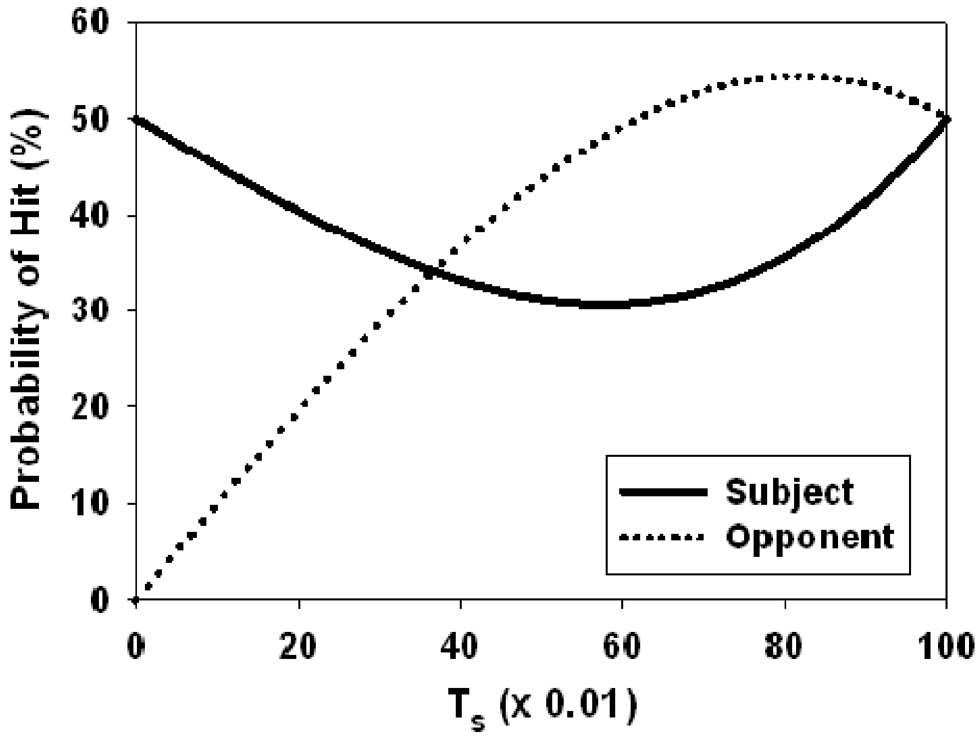

Figure 2. Mean probabilities of being hit as a function of the subject's shooting time (T_s) for completely randomized opponent's shooting times. The zone of advantage begins at T_s = 0.37 and continues to the right.

Table 1. Hit probabilities and corresponding odds ratios for the i) lowest probability of the subject being hit, ii) maximum separation (Δ) of hit probabilities, and iii) highest probability of hitting the opponent for completely randomized opponent's shooting times.

Subject's Time (T_s)	**Probability of Being Hit (%)**			**OR (kill)**	**OR (survive)**
	Subject	**Opponent**	**Δ**		
i) 0.58	30.8	48.2	17.4	1.57	1.34
ii) 0.71	32.4	53.1	20.7	1.64	1.44
iii) 0.82	36.6	54.4	17.8	1.49	1.39

3.3 Normally distributed opponent engagement time

In this case, the opponent chooses to shoot at a time that is normally distributed about some peak value. The mean probability of the subject being hit is thus determined through consideration of all possible opponent engagement times that are normally distributed about a peak value (μ) with a specified standard deviation (σ), as follows:

$$\bar{\Pr}\ \text{(subject being hit)} = \int_0^{T_s} f(\mathrm{T_o}) \cdot \mathrm{T_o} \cdot d\mathrm{T}_o \quad + \quad \int_{T_s}^{1} f(\mathrm{T_o}) \cdot (1-\mathrm{T_s}) \cdot \mathrm{T_o} \cdot d\mathrm{T}_o \tag{7}$$

$$= \frac{\left\{ \sqrt{2} \cdot \sigma \cdot \left[-\exp(-a_1^2) + (1-\mathrm{T_s}) \cdot \exp(-a_2^2) + \mathrm{T_s} \cdot \exp(-a_3^2) \right] + \sqrt{\pi} \cdot \mu \cdot \left[-erf(a_1) + (1-\mathrm{T_s}) \cdot erf(a_2) + T_s \cdot erf(a_3) \right] \right\}}{\sqrt{\pi} \cdot \left[erf(a_1) - erf(a_2) \right]}$$

where $f(\mathrm{T}_o) = \frac{1}{\mathrm{k}} \cdot \exp\left[\frac{-(\mathrm{T_o} - \mu)^2}{2\sigma^2} \right], \quad k = \int_0^1 \exp\left[\frac{-(s-\mu)^2}{2\sigma^2} \right] \cdot ds$

$$a_1 = \frac{\mu}{\sqrt{2} \cdot \sigma}, \quad a_2 = \frac{(\mu - 1)}{\sqrt{2} \cdot \sigma}, \quad a_3 = \frac{(\mu - \mathrm{T_s})}{\sqrt{2} \cdot \sigma}$$

and exp() and erf() are the exponential and error functions, respectively. Similarly, the mean probability of the subject hitting the opponent is given by:

$$\bar{\Pr}\ \text{(opponent being hit)} = \int_0^{T_s} f(\mathrm{T_o}) \cdot (1-\mathrm{T_o}) \cdot \mathrm{T_s} \cdot dT_o \quad + \quad \int_{T_s}^{1} f(\mathrm{T_o}) \cdot \mathrm{T_s} \cdot dT_o \tag{8}$$

$$= \frac{T_s \cdot \left\{ \sqrt{2} \cdot \sigma \cdot \left[-\exp(-a_1^2) + \mathrm{T_s} \cdot \exp(-a_3^2) \right] + \sqrt{\pi} \cdot \left[(1-\mu) \cdot erf(a_1) - erf(a_2) + \mu \cdot erf(a_3) \right] \right\}}{\sqrt{\pi} \cdot \left[erf(a_1) - erf(a_2) \right]}$$

Following are a few examples to demonstrate the wide range of options to ‘shape’ the opponent’s strategy using the normal distribution.

3.3.1 Scenario #1: Peak time of 0.90 with SD of 0.02

In this scenario, the opponent’s peak shooting time is 0.90 with little variance (SD = 0.02). The zone of advantage for the subject is confined between $T_s = 0.47$ and 0.90 with an optimal T_s at 0.85 (Fig. 3) where the odds ratios are 6.1 (kill) and 5.6 (survive). A shift to $T_s = 0.95$ markedly reverses the outcome. One benefit of this scenario is that it places the zone of advantage overwhelmingly to one side of $T_s = 0.50$, which lessens the possibility that a subject’s response will be misinterpreted due to *response contraction bias* (Poulton 1994), which would occur if the subject attempted to select a midpoint (i.e., $T_s = 0.5$ in the present context) when uncertain or unconfident about the outcome.

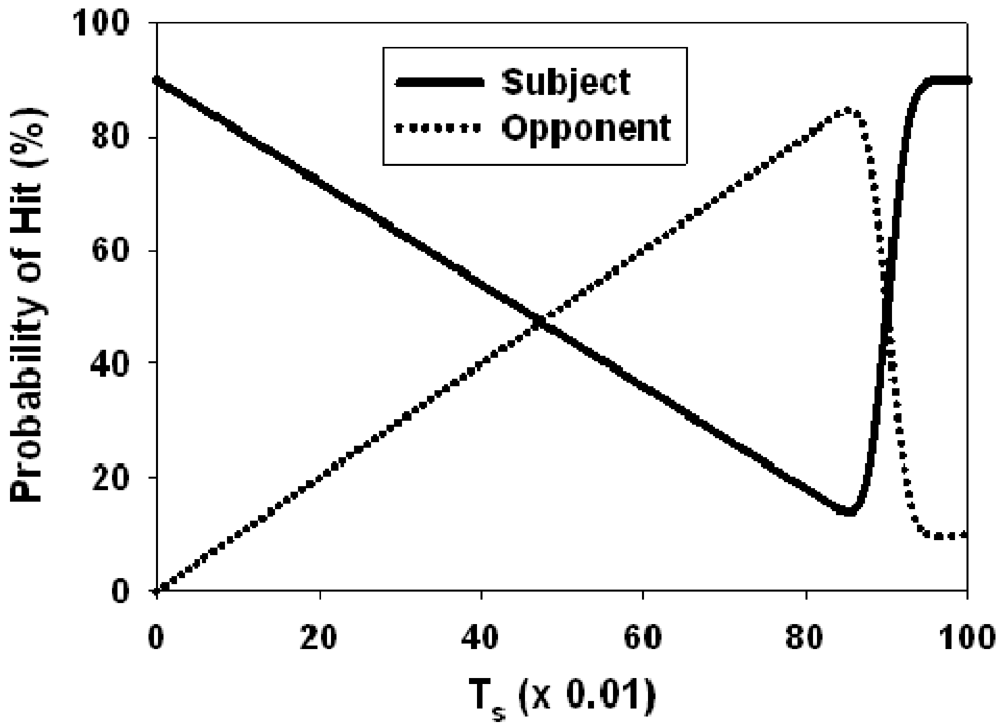

Figure 3. Mean probabilities of being hit as a function of the subject's shooting time (T_s) for scenario #1 (opponent shooting preference of μ = 0.90 and σ = 0.02).

3.3.2 Scenario #2: Peak time of 0.50 with SD of 0.02

In this instance, the opponent's peak shooting time is 0.50 with the same low variance as scenario #1. However, the zone of advantage is limited to a narrower range, and relative differences in hit probabilities are reduced, which collectively presents a more challenging scenario (Fig. 4). Note that the zone of advantage now occurs on the opposite side of T_s = 0.50. This scenario might serve as a good candidate for altering the opponent's behaviour/strategy during a test session that began with the previous scenario and then switched to the present one to test a subject's ability to adjust to a changing threat.

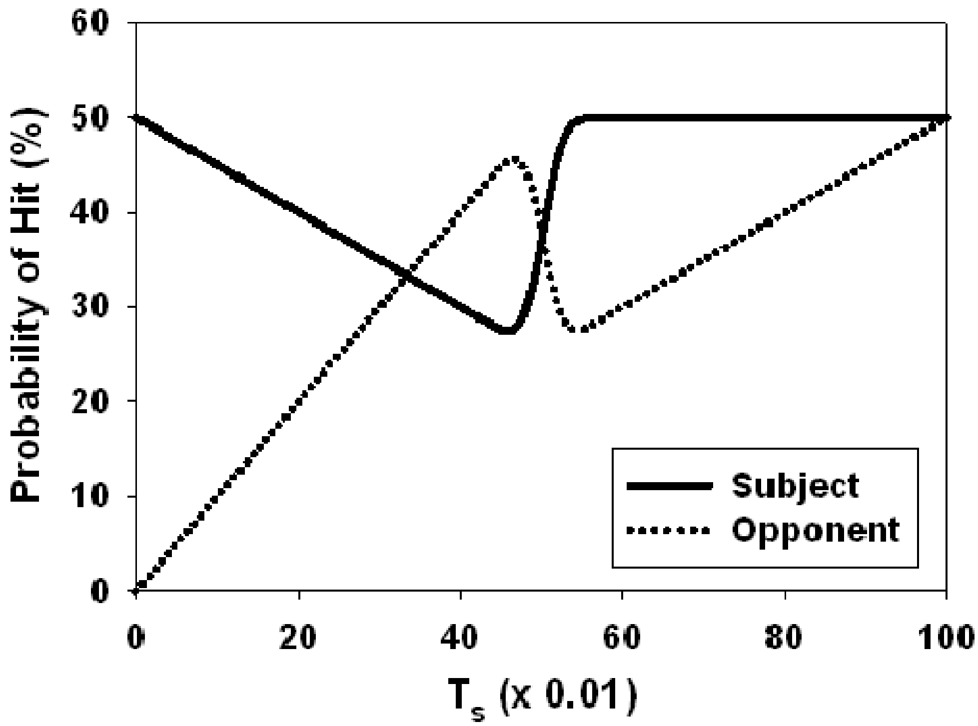

Figure 4. Mean probabilities of being hit as a function of the subject's shooting time (T_s) for scenario #2 (opponent shooting preference of μ = 0.50 and σ = 0.02).

3.3.3 Scenario #3: Peak time of 0.45 with SD of 0.10

In this variation with a broader distribution of the opponent's shooting times centered about a T_o of 0.45, four zones are generated, two of advantage and two of disadvantage (Fig. 5). Further, the former are conveniently separated, where the left-handed zone of advantage represents a cautious response (minimizing the subject's probability of being hit) while the right-handed zone of advantage represents an aggressive response (maximizing the subject's probability of hitting the opponent). This scenario offers the possibility of testing a subject's response when instructed to engage the threat with a particular bias (i.e., to strive for maximum survival or a maximum kill rate).

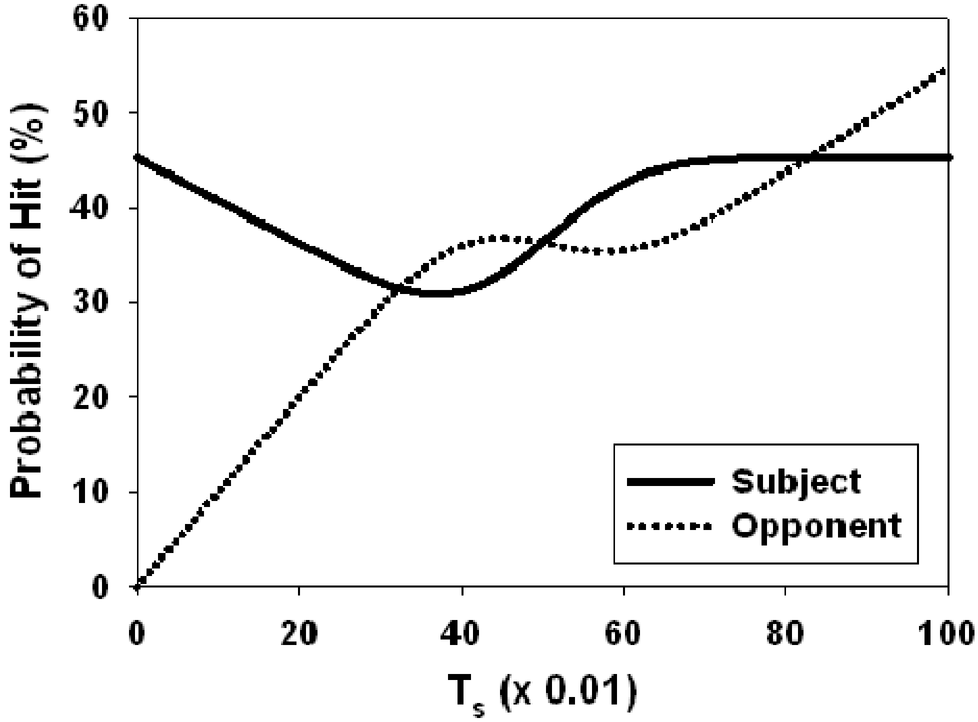

Figure 5. Mean probabilities of being hit as a function of the subject's shooting time (T_s) for scenario #3 (opponent shooting preference of μ = 0.45 and σ = 0.10).

4 Display of outcomes

Different options are available to display the outcomes of shooting engagements. The two described herein are the discrete and distributional formats.

4.1 Discrete format

The discrete format is a highly intuitive and easy to interpret illustration of whether the targets survived or did not survive an engagement. Figure 6 shows an example outcome when $T_s = 0.75$; in this case, the subject is hit and the opponent survives. Other outcomes are possible for the same T_s, as demonstrated by the various scenarios described earlier, such as when the opponent is hit and the subject survives, or when both the subject and opponent survive (hence, the nonzero-sum characterization of the game). Although there is a theoretical possibility that both the subject and opponent can be hit (if both shoot at precisely the same time and both shots hit their targets), this outcome is highly improbable and ignored since the opponent's shooting time is generally a computer-generated multi-digit (i.e., > 2 significant digits) irrational number, whereby the subject's shooting time is limited to a 2-digit number.

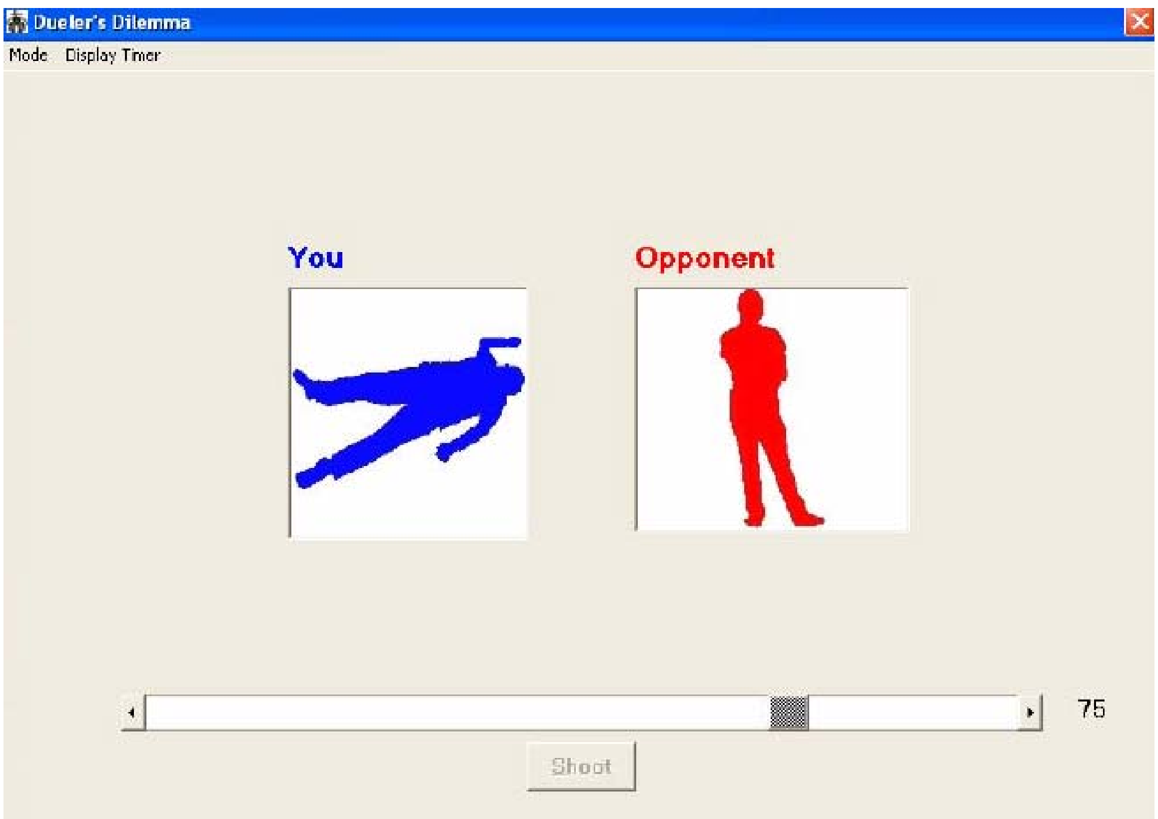

Figure 6. Example display of a possible discrete outcome when the subject shoots at a scaled time of 75 (i.e., $T_s = 0.75$).

Table 2 summarizes the possible outcomes for the discrete format. This outcome table is based on randomly-generated numbers (RN) that determine whether a particular shot will hit its target if the opportunity to shoot is available. In essence, a shot will hit its target if RN (between 0 and 1) is less than the time of the shot being fired. This time dependency of hit probabilities makes Table 2 more complicated than the 'normal' form of outcome tables, which are confined to deterministic possibilities (i.e., consequences of actions without a stochastic dependency).

Table 2. Summary of possible discrete outcomes of surviving (√) *and being hit* (X) *where T_s and T_o are the shooting times of the subject and opponent, respectively, and RN are randomly-generated numbers. The possibility that both the subject and opponent are hit is negligible and therefore ignored (see text).*

Target	**$T_o < T_s$**			**$T_o \geq T_s$**		
	$RN_1 < T_o$	**$RN_1 \geq T_o$**		**$RN_2 < T_s$**	**$RN_2 \geq T_s$**	
		$RN_2 < T_s$	**$RN_2 \geq T_s$**		**$RN_1 < T_o$**	**$RN_1 \geq T_o$**
Subject	X	√	√	√	X	√
Opponent	√	X	√	X	√	√

4.2 Distributional format

The distributional format illustrates the probabilities of the targets being hit. It is less intuitive but more informative than the discrete format, and consequently requires a higher level of cognitive processing. Figure 7 shows an example outcome using this format for the same engagement as displayed in Fig. 6. In this case, one can infer that the opponent engaged the subject at a time less than the subject's own time of shooting since the probability of hitting the opponent (31%) is less than the subject's scaled shooting time of 75. Further, one can infer that the opponent's scaled shooting time was 59 since this is equal to the probability (59%) that the subject was hit. In this case, the probability that the subject would hit the opponent is simply the probability of surviving the opponent's shot (100% – 59%) x the probability of hitting the target (75%), which equals 31%, as shown by the red bar.

Figure 7. Example display of a distributional outcome when the subject shoots at a scaled time of 75 (i.e., $T_s = 0.75$) and the opponent shoots at a scaled time of 59 (i.e., $T_o = 0.59$).

5 Summary

Dueler’s Dilemma is a ‘silent’ one person game designed to measure life-critical decision making under time pressure in a simulated confrontation with an unseen opponent. The game’s versatility has been demonstrated through various scenarios of the opponent’s strategy ranging from shooting at a specific time to complete randomization. Judicious selection of the parameters that shape the normal distribution function of the opponent is a particularly appealing option to define the shooting strategy of the opponent since it can lead to customized zones of advantage suitable for experimental investigations.

During engagements where the opponent’s shooting time is varied, the discrete and distributional outcome displays (Figs. 6 and 7) will usually change even if the subject chooses to shoot at the same time as in a previous engagement. This feature challenges the subject to deduce the strategy of the opponent, which should be evident after a sufficient number of engagements -- albeit depending on the complexity/configuration of the zones of advantage. Convergence to an optimal shooting time, whether for maximal survival or kill rate, can be used to compare responses between different preparatory conditions of the subject. For example, research possibilities include examining the behavioural responses to the instructions given to the subject (e.g., to be cautious or aggressive), and testing various hypotheses (e.g., whether and how emotional priming, pharmaceutical intervention, physiological stress, etc. would alter responses) during life-critical decision making. In essence, Dueler’s Dilemma facilitates the analysis of behaviours related to strategies and tensions involving force application and force protection.

Future plans call for an ‘intelligent’ response from the opponent based on the subject’s responses in order to simulate a higher level of realism. Guidance on an intelligent adversarial response will come from experimentation using the present platform.

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List of symbols/abbreviations/acronyms/initialisms

Pr	Probability
T_o	Time the opponent chooses to engage the subject
T_s	Time the subject chooses to engage the opponent
RN	Random number
μ	Peak value of engagement distribution
σ	Standard deviation of the engagement distribution
Δ	Separation of hit probabilities between subject and opponent

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‘Dueler’s Dilemma’ is one-person computer-based interactive game whereby the player, hereafter referred to as the subject, engages an unseen opponent in a non zero-sum silent shooting duel. Shots fired on a time scale from 0 to 100 by either the subject or opponent have a linearly increasing chance of hitting their target from 0 to 100%, respectively. However, the probability that either target is hit depends on the combination of shooting times that the subject and opponent chooses (e.g., if the opponent shoots first, the subject’s only chance of hitting the opponent depends on being missed by the opponent’s shot). The shooting times chosen by the opponent generally vary and are concealed from the subject. Further, the probability of being hit changes with each engagement, even if the subject chooses to shoot at the same time as in a previous engagement. However, patterns will emerge with a sufficient number of engagements and the subject’s objective is to converge to an optimal shooting time. After each engagement, the subject is presented with a display of the outcome, either in discrete or distributional format. Dueler’s Dilemma is presented as a versatile gamming platform suitable for researching life-critical decision making under time constraints. Its simplistic rule structure complemented by the considerable latitude in shaping the opponent’s shooting strategy makes it an attractive investigative tool for exploring behavioural responses regarding force application and force protection, as demonstrated through various scenarios.

« Dueler’s Dilemma » est un jeu informatique interactif solo dans lequel le joueur, ci-après appelé le sujet, s’engage dans un duel de tir silencieux non nul avec un adversaire qu’il ne voit pas. Les tirs déclenchés sur une échelle de temps allant de 0 à 1 par le sujet ou par l’adversaire ont une chance linéairement croissante d’atteindre leur cible de 0 à 100 % respectivement. La probabilité que chacune des cibles soit atteinte dépend toutefois de la combinaison de temps de tir que choisissent le sujet et son adversaire (p. ex. si l’adversaire tire en premier, la seule chance qu’a le sujet de l’atteindre dépend de ce que l’adversaire ait manqué sa cible). Les temps de tir choisis par l’adversaire ne sont ni prévisibles ni connus du sujet. De plus, la probabilité d’être touché change à chaque engagement, même si le sujet choisit le même temps de tir qu’au cours d’un engagement précédent. Des schémas se dégageront toutefois après un nombre suffisant d’engagements, et l’objectif du sujet est d’en arriver à un temps de tir optimal. Un affichage du résultat est présenté au sujet après chaque engagement, en format discret ou en format de distribution. Dueler’s Dilemma se présente comme une plate-forme de jeu polyvalente permettant d’étudier la prise de décision critique sous pression. Sa structure de règle simpliste et la latitude considérable laissée au sujet pour déceler la stratégie de tir de l’adversaire en font un instrument de recherche intéressant, comme en témoignent divers scénarios.

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silent duel; game theory; kill strategy; decision making