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Instruments for Studying Coincidence-Anticipation Timing Task – An Updated Systematic Review

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Abstract

A coincidence-anticipation timing (CAT) task is used to understanding the human visuo-motor system, which involves how motor control processes information involved in intercepting the moving object. **Objective**: To update a 2011 systematic review and provide best evidence regarding which instruments are being used to measure CAT tasks. **Data Sources**: Articles were identified through Web of Science and PubMed databases (search dates, 2011 to June 2017).**Study Selection**: Two reviewers independently selected studies that used a CAT task. **Data Extraction**: One reviewer extracted the search result into an Excel spreadsheet through the export option available. Two reviewers independently selected which articles evaluated a CAT task. The selected articles were compared and a new list was generated. The objectives and name of the CAT evaluation instrument were extracted from the selected articles. **Data Synthesis**: 46 studies in 136 articles were identified: 14studiesused Bassin Anticipation Timer, 18 used a custom computer program (11 different), 7 used a custom apparatus (5 different), and 7 used other commercially available CAT instruments (2 different).None ofthe instruments were specifically validated. **Conclusion**: The Bassin Anticipation Timer continues to be the most used instrument; however, there are attempts to develop computer-based applications that can replace this instrument.

Key words: Coincidence anticipation timing; coincident timing task; instruments

1. Introduction

Studies of coincidence-anticipation timing (CAT) have been conducted by investigators interested in areas such as sport skills(Clarke & Duncan, 2016; Ohta et al., 2015), child development(Cacola, Ibana, Ricard, & Gabbard, 2016),self-controlled practice(Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015), sex differences(Sanders & Sinclair, 2011) or motor aspects in cerebral palsy(C. B. M. Monteiro et al., 2014; Olivier, Baker, Cordier, Thomann, & Nougier, 2015).CAT involves both cognitive and motor processes because the subjects have to estimate the timing based on the targeted trajectory and define arm motion parameters (Forner-Cordero, Quadrado, Tsagbey, & Smits-Engelsman, 2017).In the last decade, researchers have conducted new and more sophisticated studies. We hypothesize that new instruments may be used for CAT studies. Until 2010, the majority of laboratory studies used the commercially available Bassin Anticipation Timer (Lafayette Instruments)(Sanders, 2011). In this review, we updated and expanded the earlier review conducted by Sanders (2011), and focused on instruments for measuring CAT tasks. The aims of this review are to identify the tools used in measuring coincidence-anticipation timing, identify patterns in measurement of outcomes, and make research recommendations.

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2. Methods

We followed the PRISMA (Liberati et al., 2009) guidelines (checklist items 1–11, 17–18, 21, 24, and 26). Items 1–4 were attended in the Title, Abstract, and Introduction, respectively.

2.1 Protocol and registration (PRISMA #5)

The current systematic review was not registered.

2.2 Eligibility criteria (PRISMA #6)

The following criteria were required for inclusion:1) studies that provided performances on coincidence-anticipation timing (CAT); 2) studies that were published from 2011 to June 2017;3) full-text articles available in English; and 4) studies that utilized human participants.

2.3 Information sources (PRISMA #7)

Web of Science and PubMed electronic databases were searched in June 2017 for eligible articles relating to CAT tasks.

2.4 Literature search (PRISMA #8)

We searched Web of Science and PubMed databases. For this review, we updated the research from 2011, which is the end date of the Sanders (2011) review, until June 2017 using the keywords "*coincidence anticipation timing*" with wildcards, "*coincident timing task*" and "*coincident timing*" (Table 1).

Table 1. Keywords and key topic areas in the full search strategy in each database.

Database	Search terms	Articles returned, n
1st search in Web Of Science	TOPIC: (Anticipat*) AND TOPIC: (tim*) AND TOPIC: (Coinciden*) Timespan: 2011-2017. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.	66
2nd search in Web Of Science	TOPIC: (coincident timing task) Timespan: 2011-2017. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.	51
3rd search in Web Of Science	("coincident timing") Timespan: 2011-2017. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI.	29
1st search in PubMed	Search (((Anticipat*) AND Tim*) AND Coinciden*) AND ("2011/01/01"[Publication Date]: "3000"[Publication Date])	36
2nd search in PubMed	Search "coincident timing task" AND ("2011/01/01/"[Publication Date]: "3000"[Publication Date])	9
3rd search in PubMed	Search ("coincident timing") AND ("2011/01/01"[Publication Date]: "3000"[Publication Date])	23

2.5 Study Selection (PRISMA #9)

According to the inclusion criteria stated above, two review authors independently reviewed the titles and abstracts resulting from the literature searches (Table 1). The articles were classified as "excluded", "verify", or "included". The articles in the "verify" category had the full text accessed in order to reach a final decision. Any disagreement was resolved between the two review authors. Studies excluded after full-text review were listed in the excluded studies along with the reasons for exclusion.

2.6 Data collection process (PRISMA #10)

The first author performed data extraction and collection. Data were collected by the export option in each database and were compiled into a Microsoft Excel spreadsheet for further analysis. On Web of Science, the "Save to Other Files Format" option exported "author, title, source, and abstract" data. On PubMed, the "Send to – File – Summary (text)" option exported "Author, title, DOI, source" data.

2.7 Data items (PRISMA #11)

The information elements extracted from each included article were: (1) authors and publication year; (2) objective; (3) description of samples (i.e., sample population, size, mean age, sex); (4) CAT instrument details(i.e., name, model, commercially available); (5) administration related at instrument (position, movement speed, distance travelled, target point, device to register the response); and (6) administration related to participant (i.e., position, stimulus direction).

3. Results

A flow diagram of the process used for identification of eligible studies is illustrated in Figure 1. The search of Web of Science and PubMed databases provided a total of 214articles. After adjusting for duplicates,136 remained. Of these, 80 studies were discarded because after reviewing the abstracts it appeared that these papers clearly did not meet the criteria. The full text of the remaining 56articleswas examined to extract the data items. Ten studies were excluded after the full-text read (six studies did not involve a CAT task, two had a CAT review, one had only an abstract, and another one had an animal model). A total of 46 studies met the inclusion criteria and were included in the systematic review.

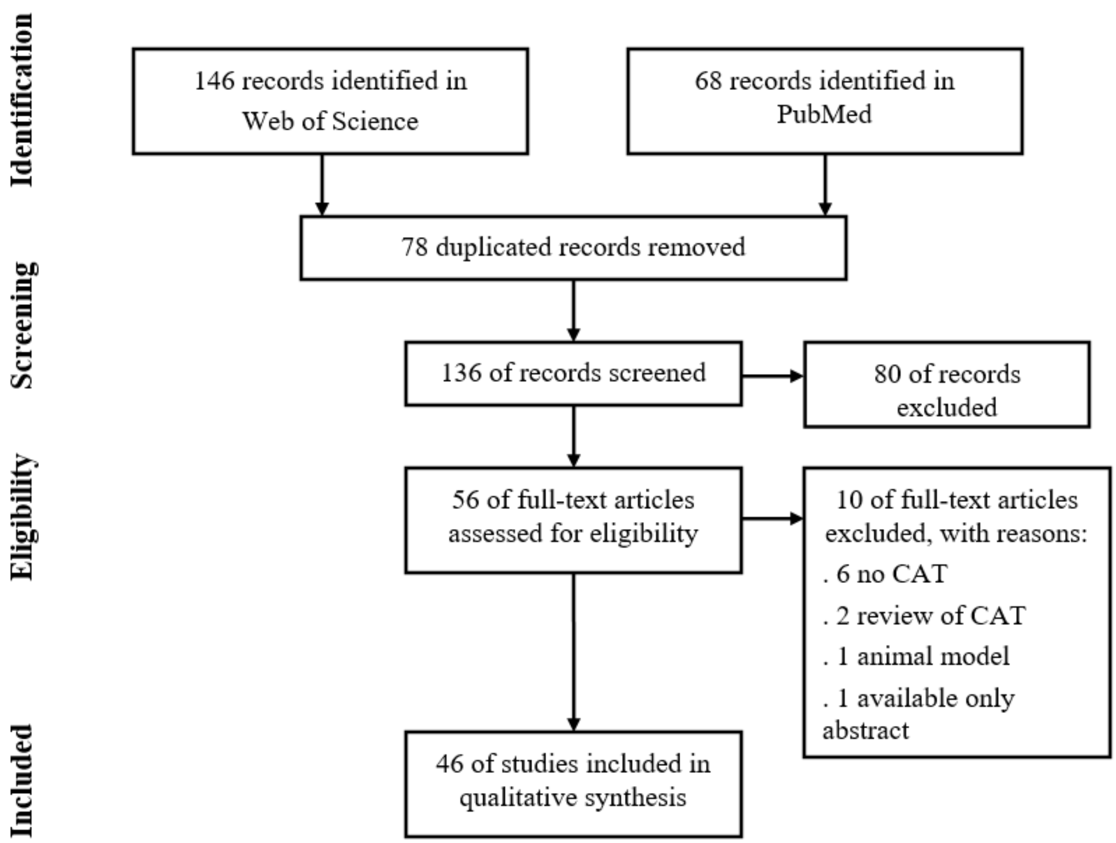


Figure 1. Flow diagram of study with number of articles accepted and rejected during the search and selection process.

After evaluating the instruments used, 46 studies including 19different instruments fulfilled the criteria for measuring CAT (Table 2).

Table 2. Distribution of studies using a coincidence-anticipation timing task measure by type of instrument, ordered by most used.

Name of instrument	Reference to articles included in the review	CA	Description of coincidence-anticipation timing task
Bassin Anticipation Timer Lafayette Instrument Co, USA n = 14	Clarke & Duncan, 2016; M. J. Duncan et al., 2016; Ceylan & Saygin, 2015; M. J. Duncan, Stanley, Smith, Price, & Wright, 2015; M. J. Duncan, Fowler, George, Joyce, & Hankey, 2015; Lewthwaite et al., 2015*;Chiviacowsky, 2014; M. J. Duncan et al., 2014; M. Duncan, Smith, & Lyons, 2013; Kim, Nauhaus, Glazek, Young, & Lin, 2013; Kirazci, 2013; Akpinar, Devrilmez, & Kirazci, 2012; Chiviacowsky, Wulf, & Lewthwaite, 2012; Rodrigues, Barbosa, Carita, Barreiros, & Vasconcelos, 2012 *: Not mentioned how to use the Bassin because it did not fit the experimental purpose.	S	The Bassin has three sections of runway (2.24 m) with the system's LED lights, 16 red lamps by each. In the first runway, other than this, there is a yellow warning lamp, and in the remaining 48 were red movement-simulating lights. The runway was connected to a controller that caused the lights to turn on and off sequentially through the length of the runway. A button is used to respond anticipating the arrival of the light at the target lamp. The sequentially lighted LED lamps illuminate in a linear pattern and are designed to give the appearance of a moving. The stimulus "velocity" is determined by how rapidly the lights were turned on and off. It is also possible to use only two sections, composing 32 red lamps, and one yellow warning. The unit has been developed to test the area of visual acuity related to eye-hand coordination and anticipation. The participant is instructed to watch a light as it travels down the runway. They must anticipate the light reaching the target and press a pushbutton to coincide with the arrival of the light at the target. TheLCD readout will display the time difference between the response and the arrival of the light at the target and indicate if the response was early or late (Bassin Manual). Is it possible to select speed from 1 to 255 mph, to select different start and ending speed for accelerate/decelerate functionality, select cue delay from 0.5 to 30.0 seconds, to randomize cue delay setting, and to elect target light (any light on the runway).
Electronic trackway Applied Office, Tokyo, Japan n = 5	Ohta, 2016;Nakamoto, Mori, Ikudome, Unenaka, & Imanaka, 2015; Ohta et al., 2015; Ohta, Ishii, Ikudome, & Nakamoto, 2014; Nakamoto, Ishii, Ikudome, & Ohta, 2012	S	An electronic trackway (4 m in length), with 200 light-emitting diodes. The LEDs were quickly turned on and off in sequence, and participants could clearly perceive the continuous motion of a target.
Custom computer program[1] n = 4	Forner-Cordero et al., 2017; Moura et al., 2016; C. B. M. Monteiro et al., 2014; Quadrado, Noriega, Forner-Cordero, &Ieee, 2014	?	A monitor displayed ten 3D cubes in a vertical column simulates a moving virtual object. The cube can 'drop' with different speeds, turned on (i.e., changed from white to green) and off sequentially (from top to bottom) until the target cube (i.e., the tenth cube) was reached. The task for the participant was to either press the spacebaron the keyboard (i.e., tangible button press task by making contact) or to make a sideward hand gesture as if hitting the target object (i.e., the more abstract gesture task, without making contact) at the exact moment the target cube turned green. A keyboard or a webcam (recorded a marker on the table in-between the monitor and the participant) can be used.
Custom computer program[2] Written in LabVIEW software	Ota, Shinya, & Kudo, 2016; Ota, Shinya, & Kudo, 2015; Ota, Shinya, & Kudo, 2013	?	A warning tone was presented to prepare the participants to get ready for an upcoming trial. After a random foreperiod interval (between the warning tone and the visual cue was randomly varied between 800 and 1200 ms in steps of 100 ms), a visual cue was presented on a computer screen as the start signal. The reference time was set at 2300 ms after the presentation of the

(National Instruments, Austin, TX, USA) n = 3			visual cue. The participant was required to press a button.
Custom computer program and apparatus[3] n = 3	Pinheiro, Marques, Tani, & Correa, 2015; Torriani-Pasin et al., 2013; Fonseca, Benda, Profeta, & Ugrinowitsch, 2012	?	The apparatus comprised: (1) one straight bar, 200 cm long, 10 cm wide and 10 cm high with 90 light emitting diodes (LEDs) placed along it with inclination, separated 1 cm from each another; (2) a wooden table, 70 cm long, 90 cm wide and 6 cm high, upon which five response keys measuring 5 cm wide and 15 cm long were placed; (3) one box, 10 cm wide, 20 cm long and 2 cm high, with five diodes to inform the subject about the coincident-timing error (feedback); (4) a computer with software, which made it possible for the diodes to be switched on and off in sequence, at different speeds. Specifically, the task was to perform a sequence of five arm movements in order to press response keys during the presentation of a visual stimulus—a sequence of LEDs lighting up—so that the last response would coincide with the lighting of a final diode. The keys should be pressed in the following sequencing: 1-2-4-3-5.
Custom computer program[4] Written in Matlab™ (R11), Mathworks, Inc., Natick, MA n = 2	Ilmane & LaRue, 2011a; Ilmane & LaRue, 2011b	?	A monitor screen was used to project a scene that consisted of 1) a red vertical bar moving at a constant velocity from the left to the right of a green horizontal; or 2) filled black circle moving downward at a constant angular velocity along a 3-D spiral path that was drawn on a virtual transparent vertical cylinder. A panel was placed 180 cm from the subject, situated at eye level. To detect the motor action of the arm, the hand made contact with a switch connected to a custom-made circuit; a simple disruption of the contact between the skin and the switch provided an instantaneous (nomechanical delay) clear Transistor-Transistor Logic (TTL) signal. A photocell was used to detect the moment of arrival of the arm at the horizontal level.
Digital Speed Anticipation Reaction Tester Takei Scientific Instruments Co. Ltd, Niigata, Japan n = 2	Koshizawa et al., 2013; Koshizawa, Mori, Oki, Takayose, & Minakawa, 2014	S	Computer display placed 1.3 m in front of participant. Participants were asked to press the button with their right thumb at the time that they anticipated the downward-moving visual target to arrive at the end of the runway. The stimulus runway was 25 cm long and the moving visual target, traveling at a constant velocity of 16.5 cm/s, took 1500 ms to move from the top to the bottom of the runway. The diameter of the target was 3.3 cm and the angle of vision from top to the bottom of the runway was 10.8^{o}.
Custom computer program: Team Bridge Games n = 2	Antunes et al., 2017*; C. B. D. Monteiro et al., 2017 *Studyprotocol	N	Ten 3D–cubes were displayed simultaneouslyin a vertical column on a monitor. The cubescreated turned on (i.e., changed from blue to green)and off sequentially (from top to bottom) until thetarget cube (i.e., the tenth cube) was reached. Thetask for the participant was to press the space bar onthe keyboard in the exact time to hitting the targetobject.
Custom computer program[5]	Cacola et al., 2016	?	Visual images are systematically projected onto a table surface at midline (90^{o}). For the "target moving towards" experiment, the target appeared at about 80 cm from the participant, and moved

Written in Visual Studio (Microsoft Corporation) n = 1			toward (closer) to the participant in 2 cm increments every 500 ms. For the "target moving away" experiment, the target appeared immediately thereafter at a location 4 cm away from the participant, and moved away in 2 cm increments, every 500 ms. Participants wore a modified commercial racquet glove and were instructed to push the center button of the keypad with their left hand when they believed that the target had arrived at their interception point. Five conditions were performed with each experiment (arm [no tool] and tools of 10, 20, 30, and 40 cm).
Custom apparatus[6] n = 1	Dascal & Teixeira, 2016	?	The electronic trackway (200 cm x 8 cm x 6 cm) with light-emitting diodes were quickly turned on and off in sequence (generating an apparent constant target velocity of 3 m/s) to produce the perception of continuous motion of a luminous stimulus (target) moving horizontally. At the end of the trackway proximal to the participant, there was a strain gauge inside a tennis hemiball filled with rigid plastic material, which was used to detect the instant of hand contact with the hemiball.
Custom computer program[7] Written in LabVIEW software (National Instruments, Austin, TX, USA) n = 1	Ikudome et al., 2016	?	A target moved horizontally from left to right toward a fixed target on the screen over 1.5 s. However, the moving target disappeared for the last 500 ms of the 1.5 s. Participants had to press the "Enter" key at the time that the moving target would have reached the top of the fixed target.
Musical sequence (drum sound)[8] with Audacity software n = 1	Olivier et al., 2015	S	The musical sequences were delivered at three different paces: slow (1.10 Hz or 65 bpm); intermediate (1.40 Hz or 85 bpm); and fast (1.75 Hz or 105 bpm). The musical sequences were listened through sound amplifiers. In the verbal condition, a tie microphone was connected to the computer to provide the response. In the motor condition, participants faced a 40×40 cm and 2 mm thin metallic surface on which two targets representing red flowers (3 cm of diameter) and distant 25 cm from each other were designed. In addition, a metallic thimble was fixed at the extremity of the index finger to make contact with one target or the other.
Custom computer program[9] n = 1	Sasada, Nakamoto, Ikudome, Unenaka, & Mori, 2015	?	Custom computer program that generated the linear motion of the objects. The target moved from the start to the interception point (a distance of 9 m) on the wall at a constant velocity (22.5 m/s). The total time of target presentation was 400 ms, an interval similar to that encountered by a baseball batter during authentic batting. Participants were required to swing a standard wooden baseball bat (coupled response) and/or press a button (uncoupled response) at the moment of the target's arrival at the interception point.
Custom computer program[10] n = 1	Abe & Sternad, 2013	?	The program emulated the virtual environment of the ball game skittles or tetherball where players throw a ball that is suspended on a string from a vertical post to hit a target skittle on the other side of the post. The participant stood ~0.6 m in front of the projection screen (width: 2.50 m, height: 1.80 m).
Custom computer	Renzi, Bovier, & Hammond, 2013	?	Linear array of LEDs placed along a wall-mounted track, 10.1 feet long and the 120 LEDs were spaced 2.02 cm apart. The

program and custom apparatus[11] n = 1			track was positioned at a height of 5.5 feet. Individual LEDs along the linear 120 LED track were lit in rapid sequence, which created the appearance of a small, moving light bar. Bar speed was randomly varied between 5, 10, 15, and 20 miles/hour (mph). Subjects were asked to press a button to stop the light bar at a specified point along the track. Subjects stood centered on the track at a distance of 4 feet.
Custom computer program[12] n = 1	Rothenberg-Cunningham & Newell, 2013	?	The program was simulates the components of American baseball. The interactive device used was a Wacom Cintiq 21UX digital tablet. A handheld, cordless stylus was used with the digital graphics tablet with an active surface area of 432 mm x 324 mm. The screen face was upright at an angle of 60º (from horizontal). The targets traveled at the velocities of 30 m/s, 40 m/s, 50 m/s, and 60 m/s and were influenced by gravity (-9.8 m.s.s.) multiplied by weightings of 0.05, 0.5, 1, and 1.5.
Custom computer program[13] n = 1	Masaki, Sommer, Takasawa, & Yamazaki, 2012	?	A clock-type rotational stimulus (diameter = 61 mm, subtending approximately 3.5º) was presented on the center of a computer monitor placed 100 cm in front of the participant. The clocklike rotated with one of two constant velocities (420 ms/cycle or 570 ms/ cycle); the peak of force exertion had to coincide with the clock after exactly one rotation. The official distance from the pitcher to the home plate is 18.44 m. The shorter interval given by one cycle of the faster rotation (420 ms) is typical of a so-called fastball covering this distance of 18.44 m at 158 km/h, whereas the longer duration of 570 ms is representative of a more average speed of 116 km/h. The CAT task required pressing the force-sensitive key such that a specified peak force was reached when the clock hand crossed the 12:00 o'clock position.
Custom computer program[14] Written in Java Script n = 1	Sanders & Sinclair, 2011	?	Hovering toy UFO projected a spot of light onto a tabletop. The UFO then moved obliquely towards the participant as it travelled to a docking station. Before reaching the docking station, the UFO and its spotlight disappeared. Participants were asked to press their space bar at the precise moment they thought the UFO's spotlight would have coincided with the center of the still visible docking station. The total journey time from starting to docking was 5 s.
Custom computer program with machine projected ball with[15] Software Phantom, Vision Research, Inc., Wayne, Nova Jersey, EUA n = 1	Weissensteiner, Abernethy, & Farrow, 2011	?	The ball machine projected deliveries of a medium pace (i.e. 120 km/h) and the participants were required to perform a series of front-foot drives, directing their shots at a target zone placed at the 'mid-on' position. Two gen-locked, high-speed Phantom cameras were used to capture the kinematics of the batsman. Each camera was connected via cables to an Ethernet box that in turn, was connected to a laptop computer. An LED event marker, linked to an infra-red 'gate' located on the opening of the ball machine and positioned in the field of view of the high-speed cameras, was used to signal time of ball release. Timing of movement initiation of the batsman relative to time of ball release was then determined.

CA: commercially available; S: sim; ?: not mentioned if commercially available; CAT: coincidence-anticipation timing; bpm: beatings per minute; n: number of studies.

Most studies (n=21, 45.7%) used a commercially available instrument; in over39% of the studies (n=18) the researchers developed a custom computer program to generate the stimulus and control the response.

The *Bassin Anticipation Timer*was used in 14 studies (30%), most of them in its standard configuration (three sections of runway and a button to register the response). Some studies made some adaptations to leave the task more real; for instance, Clarke and Duncan (2016) and Kim et al (2013) used a photoelectric beam aligned vertically below the target point so the participants could use a badminton racket to pass through it, and a baseball glove with a realistic ball-catching scenario, respectively.

Rodrigues et al (2012) proposed a task of greater complexity, and connected the Bassin runway to a 60cm x 72 cm plywood platform on which six buttons were placed in a sequence; the participants had to push the remaining five buttons sequentially (1-2-3-4-5)in a matter such that the last button-push (near theending of the runway) would coincide with the arrival of the moving stimulus at the last LED.

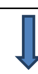
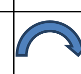
Other instruments are quite similar to the Bassin, such as the Electronic trackway by Applied Office and a custom apparatus proposed by Pinheiro et al (2015), Torriani-Pasin et al (2013), Fonseca et al (2012),Dascal and Teixeira(2016) and Renzi, Bovier and Hammond(2013).

Table 3 summarizes the information for each study included in the review (46studies). The table includes information concerning participants in each study, including the sample size, age, and sex. The remaining information includes the aims of each study, the name of the specific CAT instrument used in each assessment, how the instrument was applied (position, kind of stimulus, velocity of stimulus, distance travelled by stimulus, direction of stimulus, position target, and device used by response), and how the participant was positioned in relation to the stimulus (sitting or standing).

Table 3. Summary of the main characteristics from studies selected (publication order).

Study	Objective	Description of samples (sample population, age, sex)	CAT Model	P	K	V	D	SD	T	Register	PP
Antunes et al., 2017	Effects of practicing games in a VR environment on loneliness among elderly	Elderly 50-??yr F and M Study protocol	Custom computer program: Team Bridge Games	Vt	3D cube	400 ms	?	↓	#10	Keyboard, Webcam	Sit
Forner-Cordero et al., 2017	Learning with load and no load	60 HA 18-40 yr 25 F, 35 M	Custom computer program[1]	Vt	3D cube	4.5, 2.7 s	?	↓	#10	Webcam	Sit
C. B. D. Monteiro et al., 2017	Motor learning process during a virtual reality task	20 DS 20 TD 14-30 yr 18 F, 22 M	Custom computer program: Team Bridge Games	Vt	3D cube	400 ms	?	↓	#10	Keyboard, Webcam	Sit
Cacola et al., 2016	Internal modeling deficit with and without tools	25 DCD 23 TD 7-13 yr 21 F, 27 M	Custom computer program[5]	H	2 cm circle	2 cm each 500 ms	Max reach	↓↑	10, 20, 30, 40 cm	Button	Sit
Clarke & Duncan, 2016	Effect of carbohydrate and caffeine solutions	12 Badminton players 28 ± 9 yr 12 M	Bassin Model 35575	Dg (70-180 cm)	LED	3 mph, 5 mph	2.24 m	Twd	#48	Racket with photoelectric beam	Std
Dascal & Teixeira, 2016	Motor skills on motor performance maintenance	20 HA 19-29 yr 64 older tennis players,	Custom apparatus[6]	H	LED	3 m/s	2 m	Twd	2 m	Strain gauge	Std

		runners and exercisers 60-82 yr 40 F, 44 M									
M. J. Duncan et al., 2016	Catastrophe model	18 HA 23.6 ± 4.2 yr10 F, 8 M	Bassin Model 35575	H	LED	8 mph	2.24 m	←	#13	Button	Std
Ikudome et al., 2016	Cognitive functions in exercise program	170 elderly 52-81 yr 121 F, 49 M	Custom computer program[7]	H	?	?	1.5 s	→	1.5 s	Enter key	Sit
Moura et al., 2016	Learning in different dynamics	4 HA 4 M	Custom computer program[1]	Vt	3D cube	4.5, 2.7 s	?	↑	#10	Webcam	Sit
Ohta, 2016	Effects of oncoming target velocities on force production	20 HA 21.0 ± 1.4 yr 20 M	Electronic trackway Model AO-1M	H	LED	4, 8, 12 ms^{-1}	4 m	→	#200	Dynamometer	Std
Ota et al., 2016	Update motor planning	15 HA 21.3 ± 3.9yr 3 F, 12 M	Custom computer program[2]	H	Visual cue	?	14”	Fix	2.3s	Button	?
Ceylan & Saygin, 2015	Proprioceptive training	42 HA 21.8 ± 1.8 yr	Bassin Model 50575	?	LED	3, 5, 8 mph	?	?	?	?	?
M. J. Duncan, Stanley, et al., 2015	Performance at slow and fast stimulus speeds	16 elderly 65.6 ± 4.1 yr 7 F 9 M	Bassin Model 35575	H	LED	3, 8 mph	2.24 m	←	#13	Button	Std
M. J. Duncan, Fowler, et al., 2015	Mental fatigue	8 rugby union, football, basketball players 24.8 ± 4.1 yr 1 F, 7 M	Bassin Model 35575	Vt	LED	5 mph	2.24 m	Twd	#13	Button	Std
Lewthwaite et al., 2015	Motor learning and choices	30 HA 21.1 ± 2.02 yr 12 F, 18 M	BassinModel ?	?	?	?	?	?	?	?	?
Nakamoto et al., 2015	Experienced batters cognitively extrapolate the location of a fast-moving object	18 baseball players 20–22 yr 18 M	Electronic trackway Model AO-5N	H	LED	10, 15 m/s	4 m	→	#200	Manual switch	Sit
Ohta et al., 2015	Muscle activation characteristics	11 baseball players 21.1 ± 0.8 yr 11 M	Electronictrackway Model AO-5N	H	LED	4, 8 m/s	4 m	Twd	#200	Bat	Std
Olivier et al., 2015	Dissociating cognitive from motor aspects	11 CP 51 HC 10.5 yr 13 HA 25.5 yr 7 F, 6 M	Musical sequence (drum sound)[8]	1) Sound 2) H	1) Sound 2) Flower 3 cm diameter	65, 85, 105 bpm	-	1) Front 2) →	8th note	1) Microfone 2) Metallic thimble	Sit

Ota et al., 2015	Relationship of action plans and configuration of the gain function	37 HA 24.7 ± 4.27 yr 10 F, 27 M	Custom computer program[2]	H	Visual cue	?	14"	Fix	2.3 s	Button	?
Pinheiro et al., 2015	Skill on adaptive process of motor learning	22 HC 9.7 ± 0.7 yr 11 F, 11 M	Custom computer program and apparatus[3]	Dg	LED	168.4, 155.4, 144.3, 137.7, 126.3, 118.9 cm/s	2 m	Twd	#90	Response keys	Sit
Sasada et al., 2015	Perception of color	24 baseball players 20-23 yr 24 M	Custom computer program[9]	H	23.5 cm diameter	22.5 m/s	9 m	Twd	9 m	Bat or button	Std
Chiviacowsky, 2014	Self-controlled feedback	28 HA 22.5 ± 3.3 yr 12 F, 16 M	Bassin Model 35575	?	LED	20 mph	2.28 m	?	#48	Button	Sit
M. J. Duncan et al., 2014	Effect of caffeine ingestion	13 HA 20 ± 2 yr 7 F, 5 males 13 elderly 68 ± 6 yr 9 F, 3 M	Bassin Model 35575	Vt	LED	5 mph	2.24 m	Twd	#13	Button	?
Koshizawa et al., 2014	Effects of in the cortical region	12 HA 22.5 ± 1.6 yr 2 F, 10 M	Digital Speed Anticipation Reaction Tester	Vt	3.3 cm	16.5 cm/s	25 cm		End	Button	Sit
C. B. M. Monteiro et al., 2014	Performance in the virtual environment generalize to the natural	32 CP, 32 health 11-28yr 16 F, 48 M	Custom computer program[1]	Vt	3D cube	1.78, 2.02 m/s	?		#10	Keyboard, Webcam	Sit
Ohta et al., 2014	Effects of weighted bat warm-up on adjustment of upper limb muscle activity	7 baseball players 21.3 ± 0.8 yr7 M	ElectronictrackwayModel AO-5N	H	LED	4, 8 m/s	4 m	Twd	#200	Bat	Std
Quadrado et al., 2014	Motor learning and adaptation under mechanical perturbations	16 HA 18-40 yr 6 F, 10 M	Custom computer program[1]	Vt	3D cube	1.78, 2.02 m/s	?		#10	Webcam	Sit
Abe & Sternad, 2013	Learning in distributional and temporal structure	13 HA 23-48 yr 3 F, 10M	Custom computer program[10]	H	1.5 cm circle	Generated by participant	Generated by participant		50 cm above	Contact switch	Std
M. Duncan et al., 2013	Effect of exercise intensity at different stimulus speeds	14 HA 24.1 ± 4.9 yr 3 F, 11 M	Bassin Model 35575	H	LED	3, 5, 8 mph	2.24 m		#13	Button	Std

Kim et al., 2013	Effects of age, target location, and stimulus speed	60 baseball, football, basketball, soccer, volleyball, tennis, or hockey players 11–18 yr 60 M	Bassin Model 50575	Dg 10º	LED	7.60, 8.49, 9.83, 12.07 ms^{-1}	2.82 m	Twd	#48	Baseball glove and two infrared beams	Std
Kirazci, 2013	Effect of verbal and visual feedback	50 healthy 15–17 yr 25 F, 25 M	BassinModel ?	?	LED	2 mph	1.45 m	Front	#32	Button	Sit
Koshizawa et al., 2013	Beta band patterns	10 HA 21–23 yr 10 M	Digital Speed Anticipation Reaction Tester	Vt	3.3 cm	16.5 cm/s	25 cm	↓	End	Button	Sit
Ota et al., 2013	Relationship between risk-sensitivity and task performance	12 HA 28.8 ± 8.7 yr 6 F, 6 M	Custom computer program[2]	H	Visual cue	?	?	Fix	2.3 s	Button	?
Renzi et al., 2013	Lutein and zeaxanthin could influence visuomotor responses	106 HA 18–30 yr 73 F, 33 M	Custom computer program and custom apparatus[11]	H	LED	5, 10, 15, 20 mph	10.1 feet	?	#120	Button	?
Rothenberg-Cunningham & Newell, 2013	Age-related speed – accuracy strategies of children, adolescents, and adults	40 healthy 7–20 yr 18 F, 22 M	Custom computer program[12]	Dg 60º	25 x 25 pixels	30, 40, 50, 60 m/s	432 x 324 mm	→	Determinate by participant	Cordless stylus	Sit
Torriani-Pasin et al., 2013	Performance of individuals with DS	16 DS, 16 health 20 ± 5 yr	Custom computer program and apparatus[3]	Dg	LED	18 m/s	2.07 m	Twd	#96	Sensor	Sit
Akpinar et al., 2012	Accuracy of athletes of different racket sports	90 tennis, badminton, and table tennis players 12.4 ± 1.3 yr 45 F, 45 M	Bassin Model 50575	H	LED	1, 3, 5 m/s	2.24 m	Twd	#48	Button	Sit
Chiviacowsky et al., 2012	Manipulating participants' perception of "good" performance would have differential effects on learning	51 healthy 21.8 ± 3.4 yr 24 F,27 M	Bassin Model 35575	Front	LED	20 mph	2.28 m	Twd	#48	Button	Sit
Fonseca et al., 2012	Extensive practice contributes to adaptation	34 HA 18-35 yr 18 F, 16 M	Custom computer program and apparatus[3]	Dg 30º	LED	?	1.83 m	Twd	#96	Response box	Std

	to unpredictable perturbations in a sequential motor skill										
Masaki et al., 2012	Neural mechanisms underlying timing control and performance	16 baseball players 19-23 yr 16 M	Custom computer program[13]	Circle	Clock pointer	420, 570 ms/cycle	61 mm diameter		12:00 o'clock position	Force-sensitive key	Sit
Nakamoto et al., 2012	Influences of the subjective-objective mismatches in bat swings	8 baseball players 19-22 yr 8 M	ElectronictrackwayModel AO-5N	H	LED	4, 8 m/s	4 m	Twd	#200	Bat	Std
Rodrigues et al., 2012	Stimulus velocity effect on manual asymmetry during planning and execution	110 HA 18-30 yr 55 F, 55 M	Bassin Model 50575	Dg 30º	LED	2, 4 mph	1.52 m	Twd	#32	Button	Sit
Ilmane & LaRue, 2011b	Anticipatory postural adjustments	10 HA 29.7 $\pm$ 3.7 yr	Custom computer program[4]	Vt	3D spiral	?	19"		5100 ms	Contact with a switch	Std
Ilmane & LaRue, 2011a	Movement preparation and execution modulates anticipatory postural adjustments /focal movement coordination	10 HA 27.3 + 4.2 yr 10 M	Custom computer program[4]	Vt	Vertical bar	720, 1200, 3000 ms	4 cm		4 cm	Contact with a switch	Std
Sanders & Sinclair, 2011	Sex differences in the accuracy and precision	157 HA +18 yr 64 F, 93 M	Custom computer program[14]	Obl	Toy UFO	5 s	?		5 s	Space bar	Sit
Weissensteiner et al., 2011	Differences in interceptive skill	21 cricket batsmen 20.3-37.8 yr 21 M	Custom computer program with machine projected ball[15]	H	Synthetic cricket balls	120 km/h	?	Twd	2 m	Bat	Std

[1, 2, 3, 4]: Apparently it is the same instrument used, but it is not clear if it is exactly the same in all articles; P: apparatus position; K: kind of stimulus; V: stimulus velocity; D: distance traveled by stimulus; SD: stimulus direction; T: target position; PP: participant position; CAT: coincidence-anticipation timing; Sit: sitting; Std: standing; Dg: diagonal; Vt: vertical; H: horizontal; Obl: oblique; #: number; ?: not mentioned; bpm: beatings per minute; s: seconds; ms: milliseconds; m: meter; F: female; M: male; HA: healthy adults; yr: years old;

DCD: developmental coordination disorder; TD: typically developing; CP: cerebral palsy; Twd: toward; HC: healthy children; DS: Down syndrome; Max: maximum.

Most of the studies (n=40, 89.1%) described healthy participants, totaling 1647 people (ages ranged from 7 to 82 years, and the sex distribution was 647 females, 872 males, and 128 not mentioned the sex). Of these, 84 were baseball players (six studies)(Masaki et al., 2012; Nakamoto et al., 2012; Nakamoto et al., 2015; Ohta et al., 2014; Ohta et al., 2015; Sasada et al., 2015) and 191 were athletes of other sports (five studies)(Akpinar et al., 2012; Clarke & Duncan, 2016; M. J. Duncan, Fowler, et al., 2015; Kim et al., 2013; Weissensteiner et al., 2011). In four studies a population of 263 elderly individuals was used (Dascal & Teixeira, 2016; M. J. Duncan, Stanley, et al., 2015; M. J. Duncan et al., 2014; Ikudome et al., 2016). The study of Antunes et al(2017) will be with subjectsaged 50 years and older at an elderly reference center. Only five studies used participants with cerebral palsy(C. B. M. Monteiro et al., 2014; Olivier et al., 2015) or Down syndrome(C. B. D. Monteiro et al., 2017; Torriani-Pasin et al., 2013), or children with Developmental Coordination Disorder(Cacola et al., 2016).

In most of the studies (n=22, 47.8%), the participants performed the CAT in a seated position, and in other studies (n=17, 37.0%) they were standing. In seven studies (15.2%) it was not possible to identify the participant's execution position (Ceylan & Saygin, 2015; M. J. Duncan et al., 2014; Lewthwaite et al., 2015; Ota et al., 2013, 2015, 2016; Renzi et al., 2013).

4. Discussion

This systematic review identified 46studies in which coincidence-anticipation timing (CAT) was assessed. Among the results obtained, it should be highlighted that almost half the studies used a commercially available instrument (Bassin Anticipation Timer, Electronic trackway from Applied Office, and the Digital Speed Anticipation Reaction Tester), and that healthy people and athletes were the most frequent participants tested.We observed a clear predominance of commercially available instruments in the studies selected.

This may be because the validity of assessments based on custom computer programs is often questioned, and the timings registered by them may be biased by the operational system and hardware (Crocetta & Andrade, 2015). We found no validation study of the instruments used, not even among those that are commercially available.

The review conducted by Sanders (2011) showed that most of the studies related to CAT and involving sex differences used the Bassin timer (29 reports) or other “contrived” tasks (12 reports), and only two used real-world tasks. In our review, we observed an increase of studies using a more real environment(Cacola et al., 2016; Dascal & Teixeira, 2016; Kim et al., 2013; Nakamoto et al., 2012; Ohta et al., 2014; Ohta et al., 2015; Olivier et al., 2015; Sasada et al., 2015; Weissensteiner et al., 2011)including environments employing virtual reality(Abe & Sternad, 2013; Antunes et al., 2017; Forner-Cordero et al., 2017; Ilmane & LaRue, 2011b; C. B. D. Monteiro et al., 2017; C. B. M. Monteiro et al., 2014; Moura et al., 2016; Quadrado et al., 2014).

There was a predominance of studies with a population of athletes and healthy adults, and other populations were poorly explored, as would be expected in the elderly population. Studies have shown that the stimulus speeds played an important role, whereby exercise enhances timing performance when stimulus speed is slow but reduces performance when stimulus speed is fast(M. J. Duncan, Stanley, et al., 2015). Similarly, acute caffeine ingestion positively influences CAT performance inolder adults, and such effects might therefore be useful for older adults in enhancing ability to undertake tasks which involve interceptive actions (M. J. Duncan et al., 2014).

Currently several promising new instruments to assess CAT performance have been developed but have not yet been tested as to their validity and reliability properties in different populations. This review has emphasized that CAT instruments are used in different settings and employ different stimuli, directions, and velocities. As a result, it is likely that despite the common elements found in CAT, standard methods for the assessment of CAT do not exist. It is necessary to validate methods for measuring baseline CAT.

More than this, the Bass in simulates motion, but in fact does not use a moving object and it may be necessary to encourage the development of new research to establish validity and reliability of tasks that represent the movement in the real world, especially by making use of an ecological perspective with the use of virtual reality, for example.

5. Conclusion

The review has provided not only a list of tools used in measuring outcomes for coincidence-anticipation timing (CAT), but also a systematic evaluation of their measurement properties. The researchers' attempts to find a new instrument for CAT measurement were evident, especially with computer use. The synthesis of evidence took into account the availability of tools and the pattern for stimulus presentation. In summary, the Bassin Anticipation Timer remains the standard instrument for use in CAT measurements, and there are already attempts to develop computer-based applications that can replace this instrument, but none of them to date have presented the necessary validation.

6. Research Recommendations

1. Develop a tool to measure coincidence-anticipation timing with careful content validation for different populations.
2. Validate measurements of coincidence-anticipation timing in different populations concurrently with the Bassin gold standard.
3. Establish a protocol for use of coincidence-anticipation timing measurements in different populations.
4. Study children, adolescents, and individuals with developmental disabilities in addition to healthy adults.

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References

Abe, M. O., & Sternad, D. (2013). Directionality in distribution and temporal structure of variability in skill acquisition. *Frontiers in Human Neuroscience, 7*. doi:10.3389/fnhum.2013.00225.

Akpinar, S., Devrilmez, E., & Kirazci, S. (2012). Coincidence-anticipation timing requirements are different in racket sports. *Percept Mot Skills, 115*(2), 581-593. doi:10.2466/30.25.27.pms.115.5.581-593.

Antunes, T. P. C., de Oliveira, A. S. B., Crocetta, T. B., Antao, J., Barbosa, R. T. D., Guarnieri, R., . . . de Abreu, L. C. (2017). Computer classes and games in virtual reality environment to reduce loneliness among students of an elderly reference center Study protocol for a randomised cross-over design. *Medicine, 96*(10). doi:10.1097/md.0000000000005954.

Cacola, P., Ibana, M., Ricard, M., & Gabbard, C. (2016). Children with developmental coordination disorder demonstrate a spatial mismatch when estimating coincident-timing ability with tools. *Research in Developmental Disabilities, 48*, 124-131. doi:10.1016/j.ridd.2015.10.021.

Ceylan, H. I., & Saygin, O. (2015). Examining the Effects of Proprioceptive Training on Coincidence Anticipation Timing, Reaction Time and Hand-Eye Coordination. *Anthropologist, 20*(3), 437-445.

Chiviacowsky, S. (2014). Self-controlled practice: Autonomy protects perceptions of competence and enhances motor learning. *Psychology of Sport and Exercise, 15*(5), 505-510. doi:10.1016/j.psychsport.2014.05.003.

Chiviacowsky, S., Wulf, G., & Lewthwaite, R. (2012). Self-controlled learning: the importance of protecting perceptions of competence. *Frontiers in Psychology, 3*. doi:10.3389/fpsyg.2012.00458.

Clarke, N. D., & Duncan, M. J. (2016). Effect of Carbohydrate and Caffeine Ingestion on Badminton Performance. *International Journal of Sports Physiology and Performance, 11*(1), 108-115. doi:10.1123/ijspp.2014-0426.

Crocetta, T. B., & Andrade, A. (2015). Retrasos en la medición del tiempo con el uso de computadoras en la investigación del Tiempo de Reacción: Una revisión sistemática. *Revista de Psicología del Deporte, 24*(2), 341-349.

Dascal, J. B., & Teixeira, L. A. (2016). Selective Maintenance of Motor Performance in Older Adults From Long-Lasting Sport Practice. *Research Quarterly for Exercise and Sport, 87*(3), 262-270. doi:10.1080/02701367.2016.1188195.

Duncan, M., Smith, M., & Lyons, M. (2013). The effect of exercise intensity on coincidence anticipation performance at different stimulus speeds. *Eur J Sport Sci, 13*(5), 559-566. doi:10.1080/17461391.2012.752039.

Duncan, M. J., Fowler, N., George, O., Joyce, S., & Hankey, J. (2015). Mental fatigue negatively influences manual dexterity and anticipation timing but not repeated high-intensity exercise performance in trained adults. *Res Sports Med, 23*(1), 1-13. doi:10.1080/15438627.2014.975811.

Duncan, M. J., Smith, M., Bryant, E., Eyre, E., Cook, K., Hankey, J., Jones, M. V. (2016). Effects of increasing and decreasing physiological arousal on anticipation timing performance during competition and practice. *European Journal of Sport Science, 16*(1), 27-35. doi:10.1080/17461391.2014.979248.

Duncan, M. J., Stanley, M., Smith, M., Price, M. J., & Wright, S. L. (2015). Coincidence Anticipation Timing Performance during an Acute Bout of Brisk Walking in Older Adults: Effect of Stimulus Speed. *Neural Plasticity*. doi:10.1155/2015/210213.

Duncan, M. J., Tallis, J., Wright, S. L., Eyre, E. L., Bryant, E., & Langdon, D. (2014). The effect of acute caffeine ingestion on coincidence anticipation timing in younger and older adults. In *Nutr Neurosci* (Vol. 17, pp. 234-238). England.

Fonseca, F. d. S., Benda, R. N., Profeta, V. L. d. S., & Ugrinowitsch, H. (2012). Extensive practice improves adaptation to unpredictable perturbations in a sequential coincident timing task. *Neurosci Lett, 517*(2), 123-127. doi:10.1016/j.neulet.2012.04.041.

Forner-Cordero, A., Quadrado, V. H., Tsagbey, S. A., & Smits-Engelsman, B. C. (2017). Improved Learning a Coincident Timing Task With a Predictable Resisting Force. *Motor Control*, 1-31. doi:10.1123/mc.2016-0059.

Ikudome, S., Mori, S., Unenaka, S., Kawanishi, M., Kitamura, T., & Nakamoto, H. (2016). Effect of Long-Term Body-Mass-Based Resistance Exercise on Cognitive Function in Elderly People. *J Appl Gerontol*, 733464815625834. doi:10.1177/0733464815625834.

Ilmane, N., & LaRue, J. (2011a). Modulation of anticipatory postural adjustments in the anticipation-coincidence task. *J Mot Behav, 43*(4), 333-343. doi:10.1080/00222895.2011.594819.

Ilmane, N., & LaRue, J. (2011b). Postural and focal inhibition of voluntary movements prepared under various temporal constraints. *Acta Psychologica, 136*(1), 1-10. doi:10.1016/j.actpsy.2010.08.005.

Kim, R., Nauhaus, G., Glazek, K., Young, D., & Lin, S. (2013). Development of coincidence-anticipation timing in a catching task. *Perceptual and Motor Skills, 117*(1), 319-338. doi:10.2466/10.23.PMS.117x17z9.

Kirazci, S. (2013). Effects of Verbal and Visual Feedback on Anticipation Timing. *Social Behavior and Personality, 41*(7), 1133-1140. doi:10.2224/sbp.2013.41.7.1133.

Koshizawa, R., Mori, A., Oki, K., Ozawa, T., Takayose, M., & Minakawa, N. T. (2013). Beta band patterns in the visible and masked sections of the coincidence-anticipation timing task. *Neuroreport, 24*(1), 10-15. doi:10.1097/WNR.0b013e32835b91cf.

Koshizawa, R., Mori, A., Oki, K., Takayose, M., & Minakawa, N. T. (2014). Effects of training the coincidence-anticipation timing task on response time and activity in the cortical region. *Neuroreport, 25*(7), 527-531. doi:10.1097/wnr.0000000000000129.

Lewthwaite, R., Chiviacowsky, S., Drews, R., & Wulf, G. (2015). Choose to move: The motivational impact of autonomy support on motor learning. *Psychonomic Bulletin & Review, 22*(5), 1383-1388. doi:10.3758/s13423-015-0814-7.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gotzsche, P. C., Ioannidis, J. P. A., . . . Moher, D. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions: Explanation and Elaboration. *Plos Medicine, 6*(7). doi:10.1371/journal.pmed.1000100.

Masaki, H., Sommer, W., Takasawa, N., & Yamazaki, K. (2012). Neural mechanisms of timing control in a coincident timing task. *Experimental Brain Research, 218*(2), 215-226. doi:10.1007/s00221-012-3052-5.

Monteiro, C. B. D., da Silva, T. D., de Abreu, L. C., Fregni, F., de Araujo, L. V., Ferreira, F., & Leone, C. (2017). Short-term motor learning through nonimmersive virtual reality task in individuals with Down syndrome. *Bmc Neurology, 17*. doi:10.1186/s12883-017-0852-z.

Monteiro, C. B. M., Massetti, T., da Silva, T. D., van der Kamp, J., de Abreu, L. C., Leone, C., & Savelsbergh, G. J. (2014). Transfer of motor learning from virtual to natural environments in individuals with cerebral palsy. *Res Dev Disabil, 35*(10), 2430-2437. doi:10.1016/j.ridd.2014.06.006.

Moura, R. T., Souza, R. S., Garcia, E., Quadrado, V. H., Villalpando, M. B., Forner-Cordero, A., & Ieee. (2016, Jun 26-29). *Exoskeleton application to assist learning of a coincident timing motor task of the arm using passive mechanical perturbations.* Paper presented at the 6th IEEE International Conference on Biomedical Robotics and Biomechatronics (BioRob), Singapore.

Nakamoto, H., Ishii, Y., Ikudome, S., & Ohta, Y. (2012). Kinesthetic aftereffects induced by a weighted tool on movement correction in baseball batting. *Human Movement Science, 31*(6), 1529-1540. doi:10.1016/j.humov.2012.04.005.

Nakamoto, H., Mori, S., Ikudome, S., Unenaka, S., & Imanaka, K. (2015). Effects of sport expertise on representational momentum during timing control. *Attention Perception & Psychophysics, 77*(3), 961-971. doi:10.3758/s13414-014-0818-9.

Ohta, Y. (2016). Effects of oncoming target velocities on rapid force production and accuracy of force production intensity and timing. *J Sports Sci*, 1-9. doi:10.1080/02640414.2016.1266017.

Ohta, Y., Ishii, Y., Ikudome, S., & Nakamoto, H. (2014). Warm-up with Weighted Bat and Adjustment of Upper Limb Muscle Activity in Bat Swinging under Movement Correction Conditions. *Perceptual and Motor Skills, 118*(1), 96-113. doi:10.2466/23.25.PMS.118k15w8.

Ohta, Y., Nakamoto, H., Ishii, Y., Ikudome, S., Takahashi, K., & Shima, N. (2015). Muscle Activation Characteristics of the Front Leg During Baseball Swings with Timing Correction for Sudden Velocity Decrease. *Plos One, 10*(4). doi:10.1371/journal.pone.0124113.

Olivier, I., Baker, C., Cordier, J., Thomann, G., & Nougier, V. (2015). Cognitive and motor aspects of a coincidence-timing task in Cerebral Palsy children. *Neuroscience Letters, 602*, 33-37. doi:10.1016/j.neulet.2015.06.043.

Ota, K., Shinya, M., & Kudo, K. (2013). Suboptimal Strategy in Performing Coincident Timing Task under Risk. *Icsports: Proceedings of the International Congress on Sports Science Research and Technology Support*, 13-18. doi:10.5220/0004640600130018.

Ota, K., Shinya, M., & Kudo, K. (2015). Motor planning under temporal uncertainty is suboptimal when the gain function is asymmetric. *Frontiers in Computational Neuroscience, 9*. doi:10.3389/fncom.2015.00088.

Ota, K., Shinya, M., & Kudo, K. (2016). Sub-optimality in motor planning is retained throughout 9 days practice of 2250 trials. *Scientific Reports, 6*. doi:10.1038/srep37181.

Pinheiro, J. D., Marques, P. G., Tani, G., & Correa, U. C. (2015). Diversification of motor skills rely upon an optimal amount of variability of perceptive and motor task demands. *Adaptive Behavior, 23*(2), 83-96. doi:10.1177/1059712315571369.

Quadrado, V. H., Noriega, C., Forner-Cordero, A., & Ieee. (2014, Aug 12-15). *Experimental assessment of a coincident timing motor task of the arm under a passive mechanical perturbation.* Paper presented at the 5th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob), Sao Paulo, BRAZIL.

Renzi, L. M., Bovier, E. R., & Hammond, B. R., Jr. (2013). A role for the macular carotenoids in visual motor response. *Nutr Neurosci, 16*(6), 262-268. doi:10.1179/1476830513y.0000000054.

Rodrigues, P. C., Barbosa, R., Carita, A. I., Barreiros, J., & Vasconcelos, O. (2012). Stimulus velocity effect in a complex interceptive task in right- and left-handers. *European Journal of Sport Science, 12*(2), 130-138. doi:10.1080/17461391.2010.546059.

Rothenberg-Cunningham, A., & Newell, K. M. (2013). Children's Age-Related Speed-Accuracy Strategies in Intercepting Moving Targets in Two Dimensions. *Research Quarterly for Exercise and Sport, 84*(1), 79-87. doi:10.1080/02701367.2013.762307.

Sanders, G. (2011). Sex differences in coincidence-anticipation timing (CAT): a review. *Percept Mot Skills, 112*(1), 61-90. doi:10.2466/04.25.pms.112.1.61-90.

Sanders, G., & Sinclair, K. (2011). Sex Differences in Accuracy and Precision When Judging Time to Arrival: Data from Two Internet Studies. *Archives of Sexual Behavior, 40*(6), 1189-1198. doi:10.1007/s10508-010-9704-2.

Sasada, M., Nakamoto, H., Ikudome, S., Unenaka, S., & Mori, S. (2015). Color perception is impaired in baseball batters while performing an interceptive action. *Attention Perception & Psychophysics, 77*(6), 2074-2081. doi:10.3758/s13414-015-0906-5.

Torriani-Pasin, C., Bonuzzi, G. M., Soares, M. A., Antunes, G. L., Palma, G. C., Monteiro, C. B., . . . Correa, U. C. (2013). Performance of Down syndrome subjects during a coincident timing task. *Int Arch Med, 6*(1), 15. doi:10.1186/1755-7682-6-15.

Weissensteiner, J. R., Abernethy, B., & Farrow, D. (2011). Hitting a cricket ball: what components of the interceptive action are most linked to expertise? *Sports Biomechanics, 10*(4), 324-338. doi:10.1080/14763141.2011.629303.