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# THERMAL PROTECTION IN SMALL BOAT SPECIAL OPERATIONS

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Thermal extremes can have a significant impact on mission performance. Small boat operations present unique thermal protection problems due to the combinations of cold temperature, high wind speed, and water exposure. Successful mission performance requires the most satisfactory thermal protection available. The United States Special Operations Command (USSOCOM) identified a need to evaluate the suitability of thermal protection garments currently in use in small boat operations during cold-weather exposures (USSOCOM Tasking 2-93). The specific aim of the research project concerned the evaluation of thermal protection garments currently in use as well as several commercially available garments with potential for use in small boat operations. The evaluation consisted of determining the relative efficacy and characteristics of the garments in terms of mission-related performance as a result of cold exposures. Thermal protection garments evaluated included the Naval Special Boat Unit 12 Kokatat dry suit, the Poseidon dry suit, the British Fire Retardant Immersion Suit, the Naval Special Boat

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13. Unit 20 Viking dry suit, the British Royal Marine immersion suit Boat Operator dry suit, the British Shark exposure/survival (Fast Rescue Craft) suit, and the Mustang exposure suit. Performance was evaluated following five-hour boat transits during exposure with small boat operators wearing different thermal garments on different days. Performance was assessed with the Special Operations Forces (SOF) Mission-Related Performance measures. These measures provided standardized measures of both cognitive and physical performance. The Kokatat and Poseidon dry suits provided better thermal protection as indicated by the smallest degradation in mission-related performance measures. The Viking dry suit, the Mustang exposure suit, and the Shark survival suit provided the lowest thermal protection as indicated by the greatest decrease in performance measures following cold exposures. Subjective operator input generally supported the comparative performance findings.

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# INTRODUCTION

Thermal extremes can have a significant impact on Special Operations Forces (SOF) personnel during the conduct of their missions. With regard to thermal impact of cold-weather exposures on specific mission performance, a need was identified by the United States Special Operations Command (USSOCOM) to evaluate the suitability of thermal protection garments either currently in use or commercially available for use in small boat operations during cold-weather exposures (USSOCOM Tasking 2-93). Small boat operations present unique thermal protection problems that include operating in cold air temperatures for prolonged periods of time, as well as protecting the user from wind speeds that routinely reach thirty knots or higher. Additionally, the garments must be able to function well under severe splash and spray conditions. In the case of individuals exiting the boats for land operations, the garment must be suitable for use during small unit patrolling. Some degree of protection during brief periods of immersion is also desirable in these garments.

## *Project Objective*

The specific aim of this research project concerned the evaluation of several thermal protection garments currently in use during small boat Special Operations, along with commercially available garments with potential for use in small boat operations. The objective of the evaluation was to determine the relative efficacy and characteristics of the garments in terms of mission-related performance during cold exposures.

## *Technology Relevance*

As stated, small boat operations present unique thermal protection problems related to the combination of cold temperature, wind speed, and water exposure.

Successful mission completion requires addressing this complex combination of variables. Information obtained on the relative efficacy and suitability of thermal garments, particularly in terms of mission performance characteristics, may provide beneficial guidelines for garment options to help complete mission requirements in extreme environments.

***Background***

In order to accomplish the tasking, site visits were arranged with Naval Special Boat Squadrons One and Two. During those visits information was obtained on thermal garments currently purchased and in use and also on small boat operational requirements in various thermal environments. A site visit was also arranged with the British Royal Marines Rigid Inflatable Boat (RIB) Troop that provided additional information regarding small boat thermal protection requirements. Additionally, information was obtained about the small boat thermal protection garments used by the Naval Special Warfare Development Group (NSWDG) and the Marine Corps System Command. Further information was obtained from commercial vendors and Department of Defense (DoD) supply systems.

Two studies were conducted concerned with the evaluation of thermal protection garments. The first was conducted at the Naval Special Boat Squadron Two, Naval Amphibious Base, Little Creek, VA, and the second was conducted at the British Royal Marines Base, Poole, UK.

## METHODS

### Study One: Little Creek, VA

Based on the information obtained during the above site visits, communications with other System Commands utilizing thermal protection garments, and recommendations of small boat operators, four protection ensembles currently in use in extreme cold-weather surface transit operations were identified for research evaluation. The small boat cold-weather protection garments selected for performance evaluation included ensembles presently used by Naval Special Boat Unit (SBU)12, Naval Special Boat Unit 20, the Naval Special Warfare Development Group, and the British Royal Marines.

***Thermal Protection Suits***

It is important to note that in considering different thermal protection garments used in small boat operations, the protective undergarments and associated ancillary equipment will differ as well as the outer protective shell. From a research viewpoint it would appear appropriate to keep all undergarments and equipment constant while different outer protective garments were changed and compared. However, from an operational viewpoint this approach is inappropriate, as the ensemble configurations would not relate to operational realities and performance data obtained would have no real-world meaning or mission-related interpretation. Based on these operational inputs and the need to provide meaningful comparisons of performance, the thermal protection ensembles were evaluated as they are actually used during small boat operations. The cold-weather thermal protection garments selected for evaluation were the following:

1. Special Boat Unit (SBU) 12 Suit. This is the thermal protection garment used most regularly during cold weather operations by Special Boat Unit 12. The ensemble consists of the following:

Kokatat dry suit (W.L.Gore & Associates, Inc., Elkton, MD) with integral boots

Polartec undergarment (top and bottom)

Gortex Thinsulate gloves/ Polypro liner

Fleece Patagonia balaclava

Protec helmet/neoprene facemask

Wool socks

2. SBU-20 Suit. This was the thermal protection garment used regularly by Special Boat Unit 20. The ensemble consists of following:

Viking dry suit (Trelleborg Viking, Inc., Portsmouth, NH)

Danner boots

Heavy polypro undergarments

Camouflage Battle Dress Uniform (BDU)

Gortex Thinsulate gloves/ Polypro liner

Fleece Patagonia balaclava

Polypropolene balaclava

Protec helmet/neoprene facemask

Gator neoprene face mask

Wool socks

3. British Royal Marine Suit. This is a thermal protection ensemble regularly used by the British Royal Marines Landing Craft personnel and occasionally by British Special Boat Service (SBS) during daily small boat operations. The ensemble consists of the following:

FRIS (Fire Retardant Immersion Suit) Exposure Suit

Buffalo (similar to Thinsulate) top and bottom undergarment

Gortex Thinsulate gloves/polypro liner

Danner boots

Protec helmet/neoprene facemask

Fleece Patagonia balaclava

Wool socks

4. Mustang Exposure Suit (Hawill's Limited, Westborough, MA). This is a thermal protection garment regularly used by the NSW Development Group and SBU 20. It consists of the following:

Mustang exposure suit

Sorrel boots

Polypro undergarment

Camouflage BDUs

Gortex gloves/polypro liners

Protec helmet/neoprene facemask

Fleece Patagonia balaclava

Polypro balaclava

Wool socks

***Research Plan***

Eighteen individuals were recruited from among the Special Operations small boat community to participate in this research study. This group consisted of nine operators from Special Boat Unit 20, seven operators from Special Boat Unit 12, and two operators from the British Royal Marines. All individuals were experienced in small boat

operations. The research study was conducted at Special Boat Squadron Two, Naval Amphibious Base, Little Creek, VA during the last week of January and the first week of February 1996. The research plan required that sixteen individuals participate as subjects, with several alternates. It was planned for each operator to have the opportunity to wear one of the four thermal protection ensembles during the entire length of each of four small boat open water transits, so that each operator would be measured in each of the protection garments once during cold exposure. The cold exposures were to consist of five-hour small boat transits. (Transits were from about 0630 to about 1130 each day.) On the days of boat transits air temperature ranged from 2 to 4°C. Boats used for transit were ten-meter RIBs provided by Special Boat Unit 20.

During the first week all potential subjects and the Special Boat Squadron Two staff were briefed on all aspects of the research study, volunteers for the study were identified and briefed, and human use consent documents were obtained. Volunteers selected were then trained on the standardized SOF Mission-Related Performance assessment battery. The assessment battery consists of both cognitive measures and physical measures that relate to operational mission performance as described elsewhere (1,2,3,4). The assessment battery was located in a building adjacent to the small boat docks. To expedite post-exposure testing the laptop computers were located in a classroom type environment, and the physical testing equipment was located in a spacious closed bay environment next to the classroom.

***Cognitive Measures***

The cognitive measures were implemented in a standardized fashion on portable battery-operated computers for use in both laboratory and field settings. Briefly, there

were six cognitive tasks implemented in the SOF Mission-Related Performance measures:

1. Matching-to-Sample: This task is designed to assess an individual's ability to quickly and accurately identify a comparison stimulus that is identical to a standard stimulus presented previously. The task is concerned with short-term spatial memory and pattern recognition skills.

2. Complex Reaction Time: This task is designed to evaluate the reaction time of an individual when multiple choices must be made as to the location of the reaction time response.

3. Visual Vigilance: This task is concerned with sustained visual attention and requires an individual to continue making decisions and a rapid response to visual symbols over a time period.

4. Serial Addition-Subtraction: This task measures an individual's ability to perform simple mathematical calculations.

5. Logical Reasoning: This task measures an individual's general reasoning ability. The task presents a series of statements about the sequential arrangement of two letter characters presented. The individual must determine whether the statement about the order of the two letters is correct or not.

6. Repeated Acquisition: This task is designed to measure an individual's ability to learn, decode, or acquire a new response sequence each session.

Measurement times required about twenty to twenty-five minutes for each individual to complete a cognitive performance session. Each individual was required to perform on the cognitive tasks for a minimum of six baseline sessions.

*Physical Measures*

The physical measures of performance were implemented in a standardized fashion and data were collected automatically on laptop computer systems. Briefly, there were five tasks implemented in the SOF mission-related measures:

1. Manual Dexterity: This task is designed to evaluate fine and gross motor skills of the fingers, hands, and arms. Subjects are required to disassemble and reassemble a weapon with which they are familiar (either an M-16 carbine or an HK-MP5 submachine gun).

2. Maximal Hand-grip Strength and Endurance: In this task a hand dynamometer is used to evaluate hand and forearm muscular strength and endurance.

3. Upper Body Strength: This task quantifies strength during a high-intensity exercise for a combination of muscle groups in the upper body by having individuals perform the maximum number of pull-ups on a portable pull-up apparatus.

4. Lower Body Strength, Mobility, and Coordination: In this task individuals are required to climb and dismount a set of portable steps as rapidly as possible for one minute, while wearing a harness containing 20 kg in added weight.

5. Shooting Skills: Specially modified weapons are used to assess the ability of individuals to quickly acquire and hit a series of randomly appearing targets. Weapons have been modified to operate pneumatically using a portable pressurized gas system in a semi-automatic mode. Modifications include a laser system activated by the trigger pull of the weapon and reflective targets which record data using a lap-top computer system.

The physical measures of performance were designed to require minimal training prior to baseline data collection. Completion of the physical battery required about ten to

fifteen minutes for each individual. Individuals were required to complete at least two sessions of the physical performance tasks to be used as baseline values. The sequence of testing was consistent between baseline and post-transit sessions. The research plan required that operators be measured on the SOF Mission-Related Performance system immediately following extraction from a daily small boat exercise.

## RESULTS

### Little Creek

During the course of this research study, due to mechanical failure, logistical concerns, and extremely harsh and variable weather, one boat run during the first day and a number of operator's participation on boat runs on other days were either canceled or terminated very early. Because of the loss of data for these individuals, complete data for all operators wearing all four thermal protection garments were not obtained within the limited time that operators were made available for the research study. The data that were obtained during this study consisted of fifteen individuals, each wearing at least three different thermal protection garments on each of three different five-hour small boat transits. Additionally, equipment problems developed with the portable shooting system that prevented accurate data recording. As a result the shooting system data were not included in the data section for the Little Creek study.

An individual's data for each one of the six cognitive tasks and each one of the four physical tasks were obtained immediately following a small boat transit. Each individual's data on the performance tasks were converted into a relative score indicating percent change from baseline performance, where baseline performance was the average of the last two baseline sessions. The relative scores for all individuals were then

combined and a mean score obtained for each of the four thermal protection garments, so that a single percent change score was obtained for each of the performance measures. For each of the six cognitive measures of Matching-to-Sample, Reaction Time, Calculation, Logical Reasoning, Vigilance, and Repeated Acquisition, two relative scores were obtained: both an accuracy score (percent correct) and a time score (reaction time). For each of the four physical measurements, relative scores represent: Step Test - the maximum repetitions in one minute; Pull-ups - the maximum number of pull-ups without letting go of the bar; Dexterity - the elapsed time to field strip and reassemble a weapon. The Hand-grip task provided two separate measurement scores: maximum hand-grip pressure and the length of time the subject could maintain fifty percent of maximum grip pressure (endurance). As a result of the described loss of individual data and the wide ranges of individual variability under the conditions of data collection, detailed statistical analysis of the data was not appropriate for purposes of the present study. The results are presented for appreciation in a graphical format.

Figure 1 shows the overall change in mean cognitive performance accuracy for each of the four thermal protection garments. The bottom of Figure 1 indicates the thermal garment evaluated and beneath that is a legend indicating the six cognitive tasks that were used to evaluate the garments as follows: Memory (Matching-to-Sample task), Reaction (Complex Reaction Time task), Calculation (Serial Addition/Subtraction task), Logical (Logical Reasoning task), Vigilance (Visual Vigilance task) and Learning (Repeated Acquisition task). The left axis of Figure 1 presents the data as the percentage change from baseline. Minus numbers in performance accuracy indicate that the operators made more mistakes on that task following a boat run than during the baseline

condition. The total length of a bar indicates the total combined change for the entire mission-related performance measures. The relative contribution of each cognitive task (memory, learning, etc.) to the overall performance decrement is indicated by the different sub-segments within each bar. The overall length of the bar for the Viking suit in Figure 1, for example, indicates that a decrease in performance accuracy was greatest for this suit (-77 percent). The decrement in accuracy performance was mostly a result of decrements in memory, logical reasoning, and learning. The Mustang exposure suit showed the second greatest decline in performance accuracy, with sub-segment contributions to performance decrements similar to those of the Viking suit. The Kokatat suit and the British FRIS showed no systematic change in performance accuracy from baseline values.

Figure 2 shows the overall change in mean cognitive performance reaction times for each of the four thermal protection garments. Figure 2 is arranged in a similar fashion as Figure 1 except that negative numbers on the left axis in performance reaction time indicate that the operators took longer to complete a task following a boat run than during the baseline condition. As with performance accuracy, the Viking suit showed the greatest decrement (lengthening) in relative reaction times, and the Mustang was second in overall decrement. The decrement in cognitive reaction time for the Viking suit was a result of decrements in all six of the sub-segments. The Kokatat suit and the British FRIS showed no systematic changes in performance reaction time from baseline values.

Figure 3 shows the cumulative change in physical performance for each of the four thermal protection garments. Figure 3 is arranged in a similar fashion as Figures 1 and 2 in that negative numbers on the left axis represent the performance decrement

relative to the baseline condition. At the bottom of Figure 3 is a legend indicating the various physical measures used to evaluate the garments: Step-test, Pull-ups, Manual Dexterity, Hand-grip Maximum, and Hand-grip Endurance. The Viking dry suit and the Mustang exposure suit again showed the greatest decrement in relative physical performance scores. However, the order is reversed when compared with the cognitive performance results, with the Mustang exposure suit showing the greatest decrement and the Viking dry suit the second greatest decrement in performance. For the Kokatat suit and British FRIS, the cumulative decrement in performance is similar, approximately 60% below baseline.

## METHODS

### Study Two: Poole

Selection criteria for garment ensembles evaluated in Poole were similar to those used for the Little Creek study. In addition, based on preliminary analysis of the data obtained in Little Creek, the two highest-rated ensembles were included in this second comparative study in Poole. These two ensembles were the SBU-12 Kokatat dry suit and the British FRIS. Again, the outer shell and the associated undergarments of the selected ensembles were maintained as a unit during the course of the testing. The garment ensembles selected for evaluation were the following:

1. SBU-12 Kokatat dry suit (components listed previously).
2. British FRIS. In addition to previously listed components, the study in Poole included a Royal Navy foul weather smock and trousers made from Ventile (a closely woven long fiber cotton material).

3. Poseidon dry suit (Serious Fun Poseidon, Hauppauge, NY). This garment ensemble was used by U.S. and Canadian personnel during a Joint Forces Diving Exercise. It was also subjectively evaluated on a limited basis by NSWDG.

Closed-cell neoprene (1/4 " thickness) suit with integral hood and booties

Polypro medium weight undergarment (2 piece)

Cotton balaclava

Neoprene face mask

Protec helmet

Gortex Thinsulate gloves/Polypro liners

Wool socks

4. British Royal Marine dry suit. This garment ensemble is used regularly during small boat operations by British Special Boat Service personnel.

Immersion Suit Boat Operator (ISBO) dry suit with integral feet fitted over standard boots

Standard combat jacket (similar to U.S. BDU)

Standard combat trousers (similar to U.S. BDU)

Polypro medium weight undergarment (2 piece) (Norgie)

Knit balaclava

Neoprene face mask

Protec helmet

Thinsulate mitten

Wool socks

5. Shark Fast Rescue Craft (FRC) suit (The Shark Group, Morpeth, Northumberland, UK). This is a garment that is commercially available in the U.K. It is marketed as a cold exposure/accidental immersion/survival suit.

Shark FRC suit

Fleece undergarment (one-piece medium weight)

Cotton balaclava

Neoprene face mask

Protec helmet

Gortex Thinsulate gloves

Wool socks

***Research Plan***

Fifteen volunteers were recruited from the small boat community to participate in the research study. The group consisted of thirteen operators from British Royal Marines RIB Troop and two Navy SEAL operators attached to Naval Experimental Dive Unit (NEDU). All participants were well qualified and experienced with regard to small boat operations during cold weather. Volunteers were briefed on all aspects of the study and human use consent documents were signed and witnessed. The subjects were trained on the standardized SOF Mission-Related Performance assessment battery and baseline data were collected. Study Two was conducted at the Royal Marine Base, Poole, U.K. during the end of October and beginning of November 1996. The seventeen subjects were divided into five three-man teams, with two alternate subjects. Five RIB transits were planned, each lasting a total of five hours. In order to accommodate the fifteen subjects, two boats were used for each transit, with three teams in one boat and two teams in the

second boat. The RIBs left the dock at approximately 0630 each morning and returned at approximately 1130. Transits were planned to represent operational exercises as closely as possible and were conducted at operational speeds dependent on sea conditions. On the five days of transit, sea state ranged from 4 to 6, winds ranged from 30-38 knots, air temperature ranged from 5-10 °C, and boat speeds averaged 40-50 knots (except for planned stops representative of operational needs). Boats were provided by RIB Troop, Royal Marines, Poole, and were 8.5 meters in length. The matrix of transits vs. subjects vs. garment ensembles allowed all subjects to wear all ensembles.

***Cognitive Measures***

Cognitive measures employed for Study Two in Poole were identical in content and administration to those used for Study One in Little Creek and listed previously in this document. Laptop computers used for both baseline and post-transit cognitive testing were located in a building adjacent to the boat dock. The RIBs departed from and returned to this dock each day.

***Physical Measures***

Four of the physical measures were identical in content and administration to those used in Study One and listed previously. The additional physical measure of performance that had been unavailable for Study One was the test of shooting skill. A description of this test is also listed in an earlier section. The physical test battery was located in a large open bay building that housed the RIB Troop gear storage and repair facility. This building was also adjacent to the boat dock, thus minimizing elapsed time between docking and the beginning of post-transit testing.

## RESULTS

### Poole

A detailed description of how collected data were converted to a relative percent change from baseline is presented in the Little Creek Results section. This format was followed for the Poole data.

Figure 4 shows the overall change in mean cognitive performance accuracy for each of the five thermal protection garments. The figure follows the same format as presented in Figure 1 for the Little Creek data. The overall length of the bar for both the Kokatat and the British FRIS garments showed a spread of accuracy performance change around zero percent as had been shown for these two suits in the Little Creek study. This indicates rather minimal changes in the accuracy of performance for these two suits due to the impact of boat transits. The Poseidon suit and the British ISBO suit also did not show any major decrements in accuracy of performance. The overall length of the bar for the Shark suit indicates that performance accuracy was the worst for this suit, about a 40 percent decrement in performance. Most of the performance accuracy decrement with the Shark suit was contributed primarily by decrements in memory and learning sub-segments.

Figure 5 shows the overall change in mean cognitive performance reaction times for each of the five thermal protection garments. Figure 5 is arranged in a similar fashion as Figure 2 for the Little Creek data. Figure 5 indicates that there were no consistent differences among the five suits in terms of the impact of cold boat transits on cognitive reaction time except that the Shark suit showed the greatest decrement in performance.

Figure 6 presents the cumulative change in mean physical performance for each of the five garment ensembles. As with the Little Creek results, decrements in physical performance are demonstrated with all ensembles. However, the pattern of total performance decrement among the ensembles is different from that seen in Little Creek. The garment ensembles with the smallest cumulative performance decrement are the Poseidon and British FRIS, with the Poseidon demonstrating only slightly better results than the FRIS. The Kokatat and ISBO show very similar intermediate results (~65% below baseline) when compared with the other ensembles, while the Shark FRC post-transit results are almost 90% below baseline.

***Operator Evaluation***

The operators were given the opportunity to provide their own subjective comments regarding each of the thermal protection ensembles. This information is presented here in support of the project tasking to determine the relative efficacy of the thermal protection garments:

**Special Boat Unit 12 Suit (Kokatat):** This is a dry suit with integral boots. It was subjectively rated highest overall by operators. It remains dry even when immersed. The boots were found to be warm but clumsy for some operations. There is adequate room for additional undergarments for extreme cold.

**Poseidon Suit:** This suit also remains dry even when immersed. It was found to be slightly restrictive. The fit of the suit must allow for additional undergarments to stay warm during inactivity. It was subjectively rated only slightly lower than the Kokatat.

**ISBO Suit:** This British dry suit remains dry when immersed. The suit has adequate room for additional undergarments. It is very similar to the Special Boat Unit 12 Kokatat in fit and appearance. It was rated equal to the Kokatat for comfort.

**FRIS:** This British dry shell also remains dry even when immersed. It was found to be very lightweight. The fit of the suit must allow for additional undergarments during extreme cold. The suit was found to be slightly restrictive. The suit was rated equal to the Poseidon for comfort.

**Viking Suit:** This suit remains dry but was found to be restrictive for boat work when used with adequate undergarments. Operators had difficulty fitting boots with the suit. The suit received an intermediate rating.

**Shark Suit:** This is a British survival suit. It was found to remain warm when dry. It is somewhat bulky. A major problem with the suit is that it does not stay dry during boat transits. It does not have a neck seal, which was a major issue during heavy seas. The suit floods during immersion. The suit was rated the lowest for small boat operations.

**Mustang Suit:** This is an alternative shell exposure suit. It remains warm when dry. The suit has significant leakage at the neck and zippers. The suit was found to be rather bulky. The suit was rated very low for boat operations, equal to the Shark suit.

## DISCUSSION

The patterns of decrement in cognitive and physical performance demonstrated during the Little Creek and Poole studies can be viewed in a variety of ways. First, some performance decrements were evident with all garment ensembles; therefore, the most suitable garments would be those that minimize overall changes in performance. Second,

determining which garment ensemble or ensembles are more suitable should take into account changes in the specific test components that comprise the cumulative change in performance. Under the conditions encountered during the Little Creek study the Kokatat suit and British FRIS demonstrated the smallest total change in cognitive and physical performance, while the Mustang and Viking suits demonstrated the greatest total change. The accuracy and reaction time changes with the Viking and Mustang suits involved decrements in all of the cognitive sub-tests, with very minor performance changes for the Kokatat suit and British FRIS. The smaller change in physical performance with the Kokatat suit and FRIS can be attributed mostly to smaller decrements in step-test and pull-up results (physical tasks requiring maximal efforts with large muscle groups) and to a lesser extent decrements in manual dexterity (FRIS) and hand-grip endurance (Kokatat).

Under the conditions encountered during the Poole study there were no consistent cognitive performance differences among four of the suits, with the greatest overall decline in performance found with the Shark suit. The Poseidon and British FRIS demonstrated the smallest physical performance change from baseline -- again due to smaller decrements in step-test and pull-up results, but also because of either no change or minimal change in shooting performance. It may be noteworthy to approach these results from the perspective of the Special Forces operator. Under the conditions described in these two studies the benefits provided by some suits over others appear not only to be a result of minimizing performance decrements for tasks mobilizing large muscle groups but also by minimizing degradation of shooting performance, which is a complex multi-faceted skill. Also of note may be the results that indicate that tasks requiring both fine and gross motor skills of the hand and forearm are degraded rather

consistently (except for the Kokatat at Little Creek) across all garment ensembles in both studies. These results should not be surprising given that in most cases hand protection was consistent among all ensembles, even among those used in Little Creek vs Poole. However, these results do emphasize the negative performance impact of cold-weather small boat operations on manual dexterity and hand-grip strength and endurance. Improvements in hand protection may be an issue that should be addressed as a separate component of the larger evaluation of thermal protective garments used during cold-weather small boat operations.

## SUMMARY

Small boat operations in Special Operations present unique thermal protection problems related to the combination of cold temperature, high wind speed, and cold-water exposure. Successful mission completion requires addressing this complex combination of variables. Information obtained on the relative efficacy and suitability of thermal protection garments may provide beneficial guidelines for garment options to help complete mission requirements in extreme environments. The current tasking sought to evaluate several thermal protection ensembles either currently in use or commercially available for use during small boat Special Operations. The objective of the evaluation was to determine the relative efficacy of the ensembles through assessment with the SOF Mission-Related Performance measures. Thermal protection garments evaluated included the SBU-12 Kokatat dry suit, the Poseidon dry suit, the British FRIS, the SBU-20 Viking dry suit, the British ISBO dry suit, the Mustang exposure suit, and the British Shark survival suit. Performance was evaluated following five-hour boat transits during cold-weather exposure with small boat (RIBs) operators wearing different thermal

protection ensembles on different days. The SOF Mission-Related Performance measures provided standardized assessment of both cognitive and physical performance following boat operations. The Kokatat and Poseidon dry suits and British FRIS provided better thermal protection as indicated by the lowest degree of degradation in mission-related performance measures. The Viking dry suit, the Mustang exposure suit, and the Shark survival suit provided the least thermal protection as indicated by the largest decrease in performance measures following small boat operations. Subjective operator input regarding the different thermal ensembles supported the comparative performance findings.

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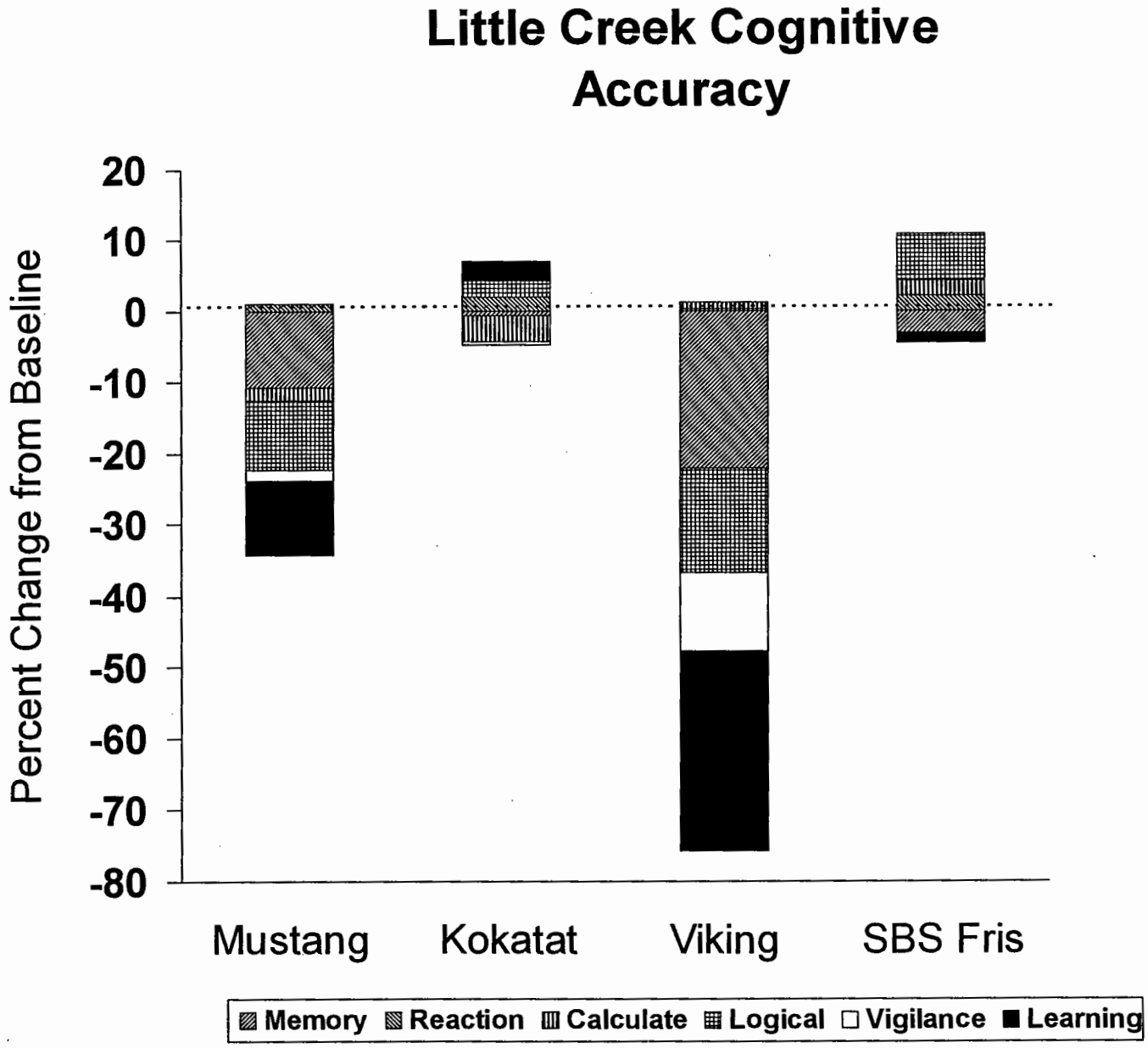
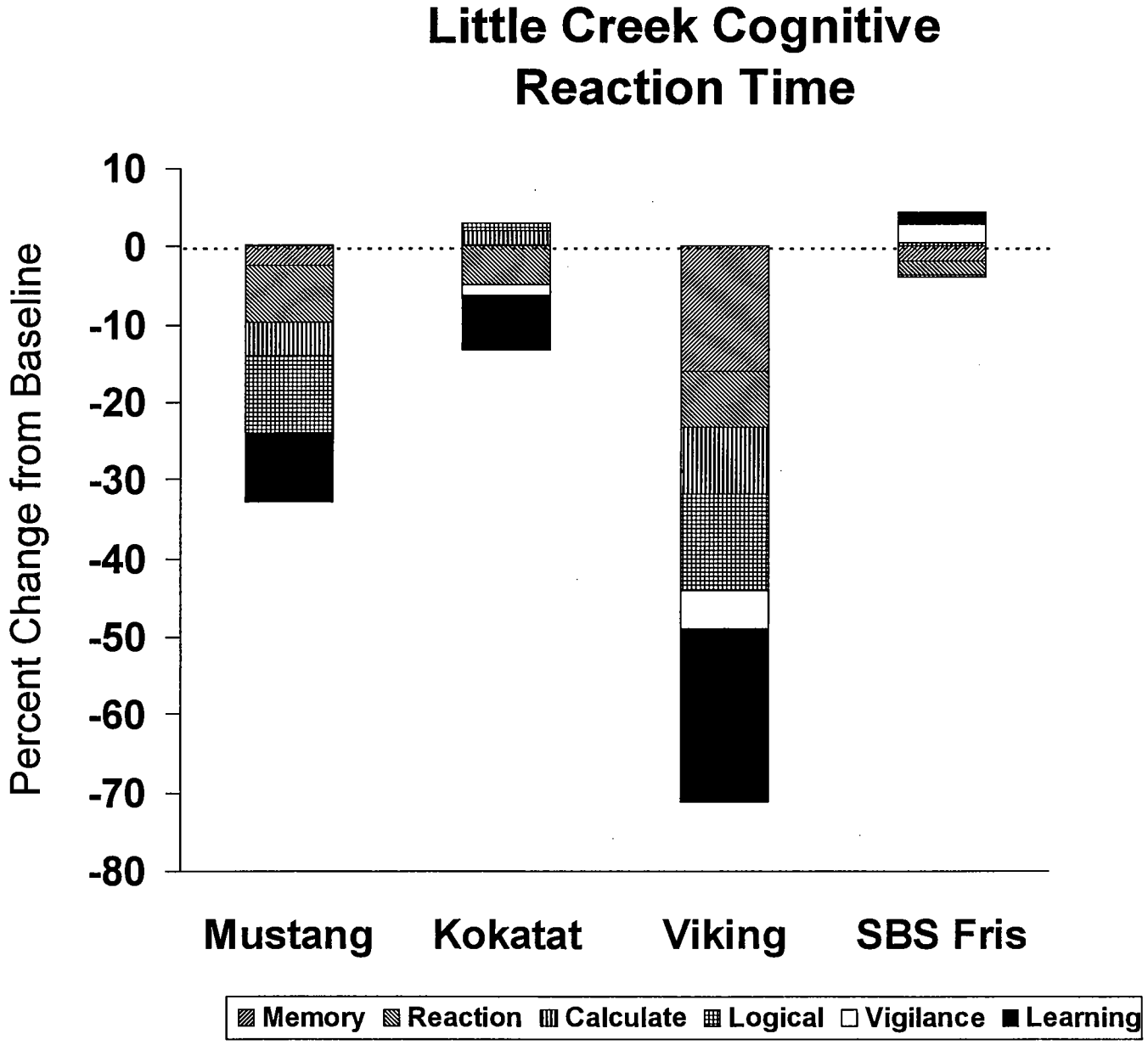
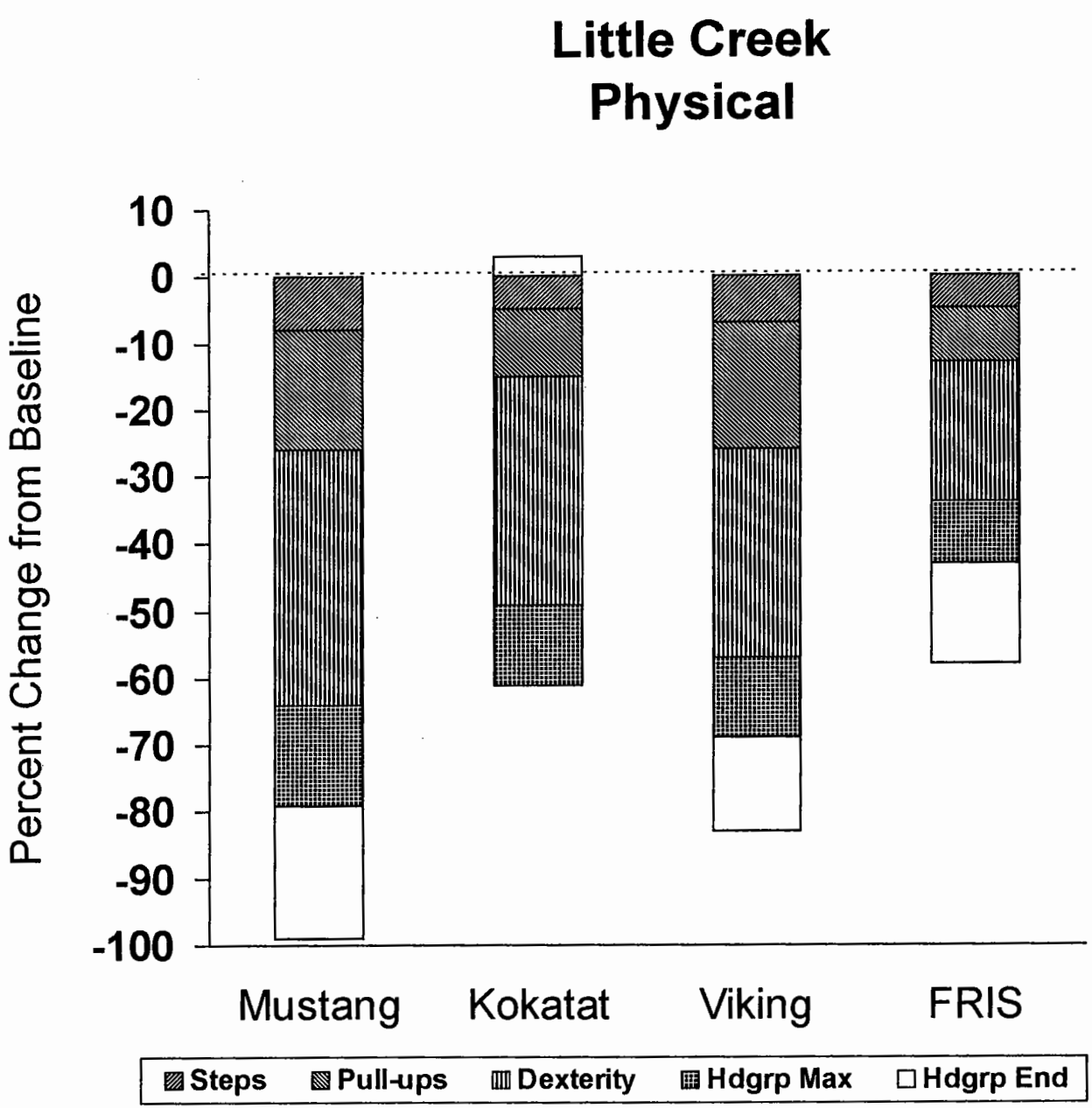
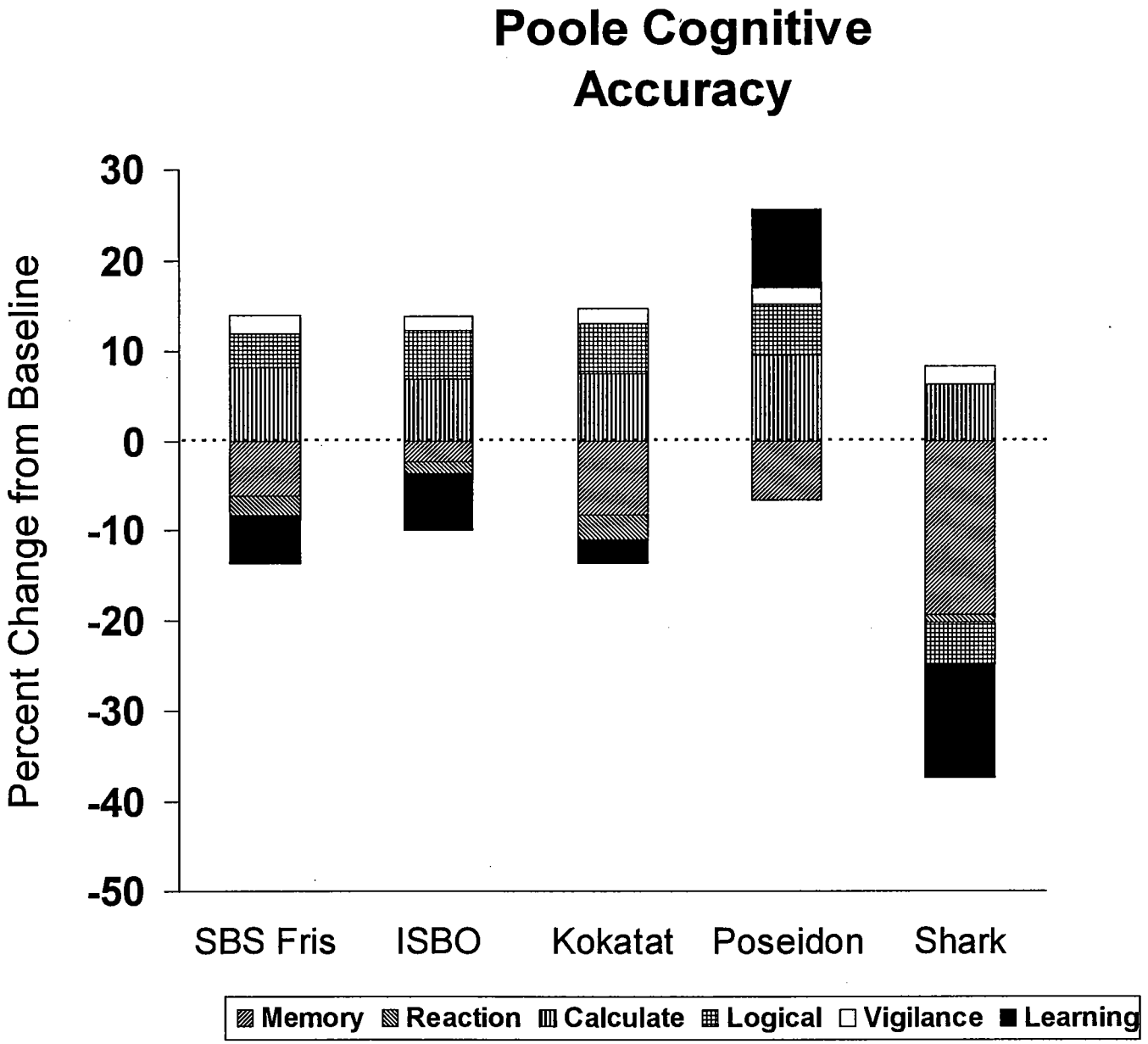
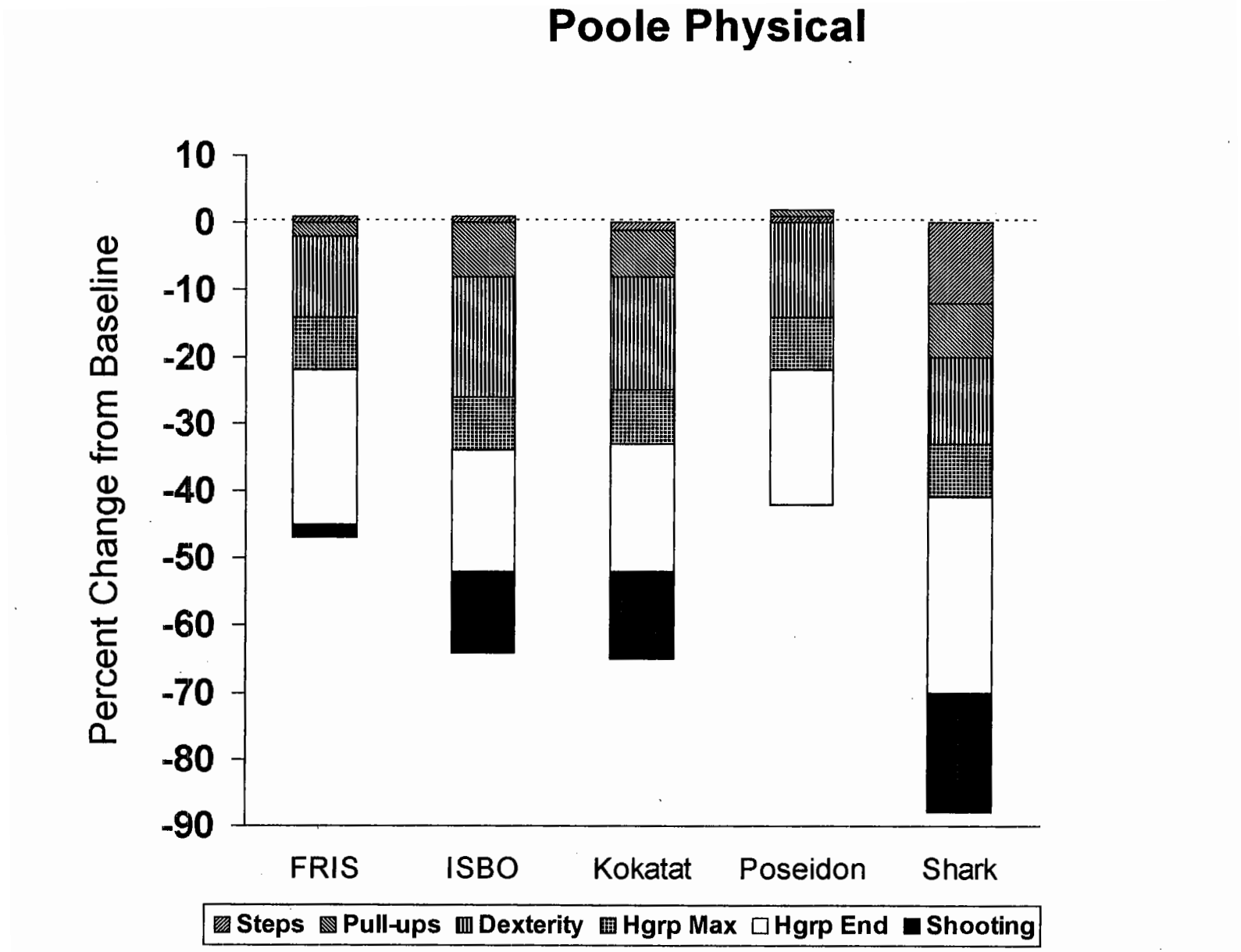
4. Hyde, D., Thomas, J. R., Schrot, J., and Taylor, W. F. Quantification of Special Operations Mission-Related Performance: Operational Evaluation of Physical Measures. Naval Medical Research Institute Report, NMRI 97-01, February 1997.

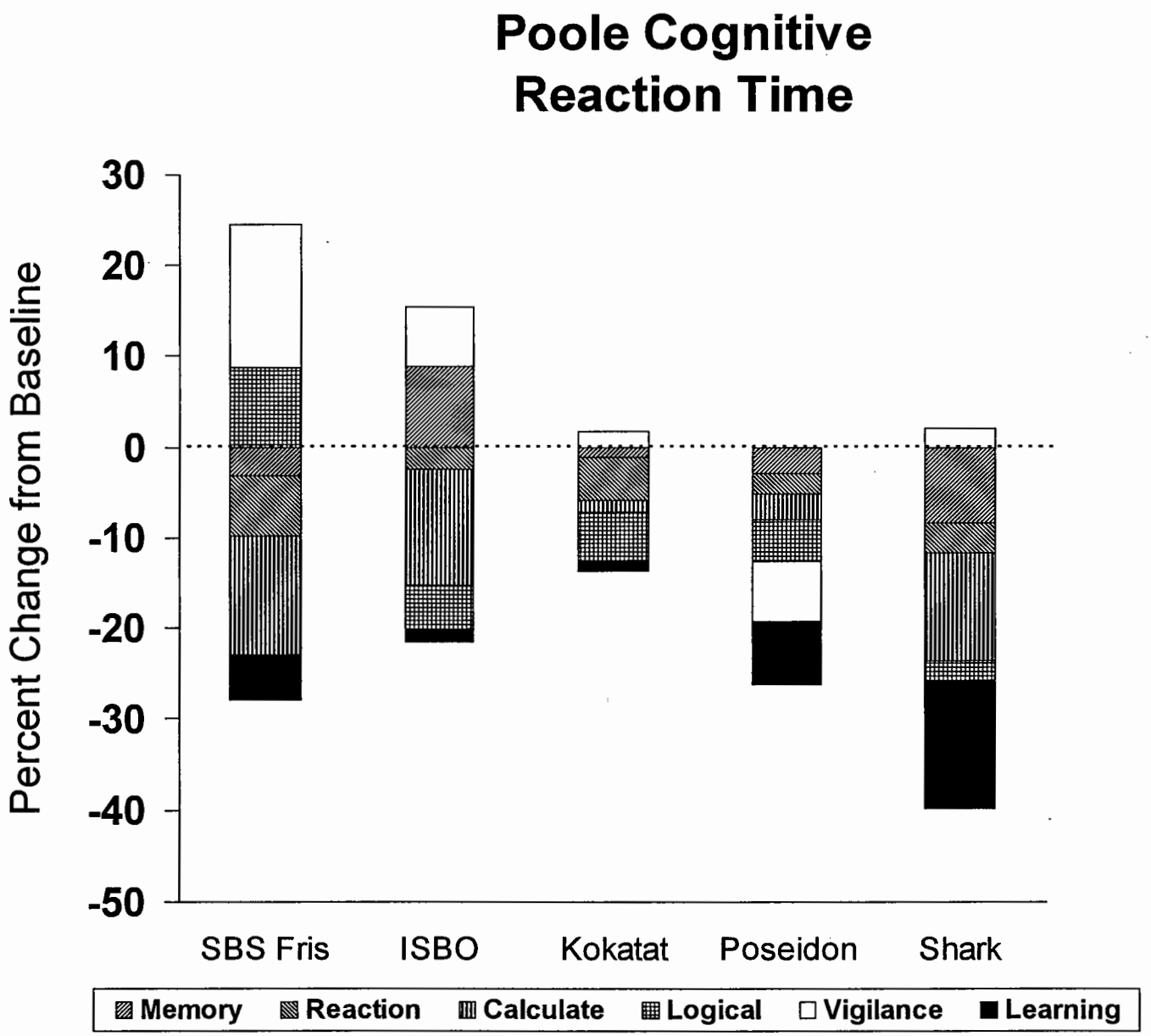

Little Creek Cognitive Accuracy
Percent Change from Baseline
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
Mustang
Kokatat
Viking
SBS Fris
Memory
Reaction
Calculate
Logical
Vigilance
Learning


Little Creek Cognitive Reaction Time
Percent Change from Baseline
10
0
-10
-20
-30
-40
-50
-60
-70
-80
Mustang
Kokatat
Viking
SBS Fris
Memory
Reaction
Calculate
Logical
Vigilance
Learning


Little Creek
Physical
Percent Change from Baseline
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Mustang
Kokatat
Viking
FRIS
Steps
Pull-ups
Dexterity
Hdgrp Max
Hdgrp End


Poole Cognitive Accuracy
Percent Change from Baseline
30
20
10
0
-10
-20
-30
-40
-50
SBS Fris
ISBO
Kokatat
Poseidon
Shark
Memory
Reaction
Calculate
Logical
Vigilance
Learning


Poole Physical
Percent Change from Baseline
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
FRIS
ISBO
Kokatat
Poseidon
Shark
Steps
Pull-ups
Dexterity
Hgrp Max
Hgrp End
Shooting


Poole Cognitive
Reaction Time
Percent Change from Baseline
30
20
10
0
-10
-20
-30
-40
-50
SBS Fris
ISBO
Kokatat
Poseidon
Shark
Memory
Reaction
Calculate
Logical
Vigilance
Learning